

**Comprehensive Framework for Sustainable
Container Port Development for the
United States East Coast**

Year One Final Report

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and Young-Tae Chang**

October 11, 2001

URI – TC Project No. Grant 536106

**UNIVERSITY OF RHODE ISLAND
TRANSPORTATION CENTER**

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1. Report No	2. Government Accession No.	3. Recipient's Catalog No.
URITC FY99-06	N/A	N/A
4. Title and Subtitle Comprehensive Framework for Sustainable Container Port Development for the United States East Coast: <i>Year One Final Report</i>	5. Report Date October 11, 2001	6. Performing Organization Code N/A
7. Authors(s) Thomas Grigalunas, Meifeng Luo and Yong-Tae Chang	8. Performing Organization Report No. N/A	
9. Performing Organization Name and Address Dept. of Environmental and Natural Resource Economics Korea-America Joint Marine Policy Research Center University of Rhode Island Kingston, RI 02881	10. Work Unit No. (TRAIS) N/A	11. Contract or Grant No. URI 536106
	13. Type of Report and Period Covered Final	
12. Sponsoring Agency Name and Address University of Rhode Island Transportation Center 85 Briar Lane	14. Sponsoring Agency Code A study conducted in cooperation with U.S. DOT	
15. Supplementary Notes N/A		
16. Abstract <p>A framework is presented that links financial, economic and environmental issues facing development of container ports along the US East Coast. First, container trends and issues are summarized. Then, key elements of the framework are outlined. These elements include (1) a national container port demand simulation model, (2) a container terminal invest feasibility (discounted cash flow (DCF)) model, and (3) an examination of potential, generic environmental issues at ports and their mitigation. The framework is intended to establish concepts and methods that will allow for the eventual estimation of the size and distribution of economic benefits and costs to (1) a container terminal operator, (2) state residents and (3) the nation due to a variety of policy issues (e.g., container port development; changes in environmental regulations, energy costs, or sources or markets for containerized goods; temporary disruptions at facilities, etc.). Example, simplified applications are given to illustrate the concepts and methods used in the framework, the many sources of uncertainty faced and alternative approaches for dealing with uncertainty and risks posed at various levels. Approaches used include use of simulation techniques, DCF, sensitivity analyses, "worst case" analysis, Monte Carlo methods and dynamic, discrete event model.</p> <p>We stress that the framework, methods and results given in this report are primarily illustrative and not intended to be conclusive. Analyses during Year Two of the project will apply, extend and refine many of the estimates given this Year One report. A more definitive analysis, e.g., for a proposed terminal or for other state, regional or national policy issues, requires the availability of specific marked analyses and terminal development plans and costs much beyond the information and resources available for the Year One Report.</p>		
17. Key Words Container ports, economics, financial analysis, environmental economics, benefit-cost analysis, simulation	18. Distribution Statement No restrictions. This document is available to the Public through the URI Transportation Center, 85 Briar Lane, Kingston, RI 02881	
19. Security Classif. (of this report) N/A	20. Security Classif. (of this page) NA	21. No. of Pages 22. Price 116 NA

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Acknowledgements

The authors wish to express their appreciation to Dr. Richard Horn, Executive Director of the University of Rhode Island Transportation Center (URITC), for his many constructive comments on an earlier version of this report. We also thank an anonymous reviewer who provided many valuable comments on a draft of this report. Dr. James J. Opaluch made many helpful suggestions, as did Dr. Bong Min Jung, Mr. CK Kim, and Dr. Christopher Anderson. We also wish to recognize the encouragement and support of Prof. K. Wayne Lee, R & D Director of the URITC, throughout this project.

We are very grateful to the many individuals at the ports of New York and New Jersey, Norfolk, Charleston, Seattle, Long Beach, Vancouver, Baltimore, and at the Panama Canal Authority, who gave generously of their time during our site visits. We also benefited from the many comments and questions raised by colleagues and many members of the Rhode Island community during several seminars. To those and others who contributed in one way or another to this project, we want to express our sincere appreciation.

Thanks also are due the anonymous reviewers of our proposals for their many helpful suggestions. At the same time, the usual caveat applies that we alone are responsible for any remaining errors.

Last but certainly not least, a special note of appreciation is due Ms. Cathy Breese, secretary for the Korea-American Joint Marine Policy Research Center, who provided able secretarial support.

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October, 2001

Comprehensive Framework for Sustainable Container Port Development for the United States East Coast

Report on First Year Research

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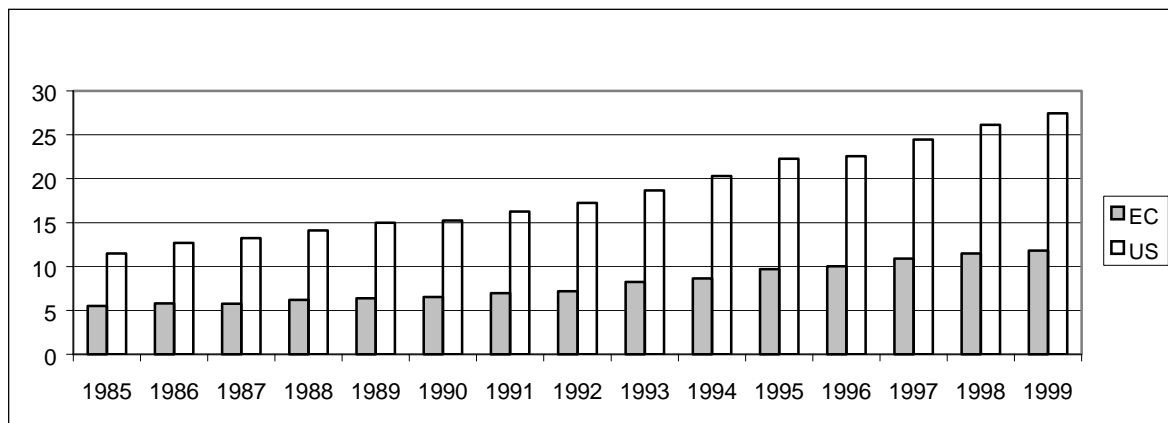
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INTRODUCTION

I. A. BACKGROUND AND ISSUES

Seagoing international trade moved on container ships is a major factor in the United States economy. In 1999, some 26 million container boxes (measured as “twenty-foot equivalent units” or TEUs) moved through US ports (U.S. Dept. of Trans., Maritime Administration (MARAD), 1999)¹ (Figure I-1). Container shipments through US ports grew about 6 percent annually over the past decade, twice the recent growth rate in US Gross Domestic Product, and are projected to increase at a 7 percent rate from 1999 to 2004 (MARAD, 2001).

Table I-1. Container Volume (East Coast vs US Total), 1985 to 1999 (million TEUs)



Source: MARAD (2000)

Existing US container ports cannot handle the projected growth in container shipments, nor can many ports, particularly on the East Coast, accommodate the larger container

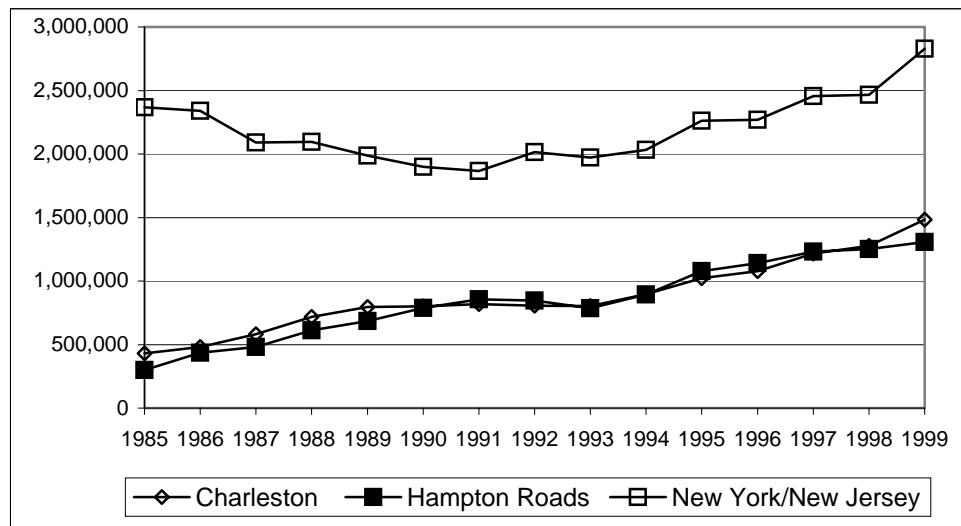
¹ A summary of US and Canada container port trends see, e.g., Chang, Grigalunas and Luo (1998; 1999).

vessels increasingly used in international shipping on long routes. As a result, vast efforts are underway throughout much of the United States and Canada to deepen berths and channels, improve terminal (dock and yard) efficiency, expand existing and construct new terminal facilities, and improve intermodal links (hereinafter, collectively referred to as “port development”).

Throughout the United States, however, proponents of port development face major challenges. Perhaps foremost among these are environmental concerns (real and perceived) with dredging; filling of open water areas; localized traffic, air pollution, and noise; loss of open space; and other potential adverse environmental effects of port development. Other challenges include financial risks for private operators and also for states due to the major onsite and offsite investments often needed to support container port development and the nature of the intense competition within the industry.

Shipments through East Coast container ports, the focus of this study, comprise about 48 percent of all recent US container moves (Figure I-1). Among the largest East Coast ports (those handling more than 1 million TEU in 1999), the Port of New York/New Jersey (PNYNJ) is by far the dominant US port (Figure I-2), followed by Charleston, SC and Hampton Roads/Norfolk, VA. Container activity also has increased for most – but not all – “second tier” East Coast US and Canadian ports over the past decade (Figures I-2, I-3).

**Figure I-2. Container Throughput of Major (> 1million TEU)
US East Coast Ports, 1985-1999 (in TEUs)**

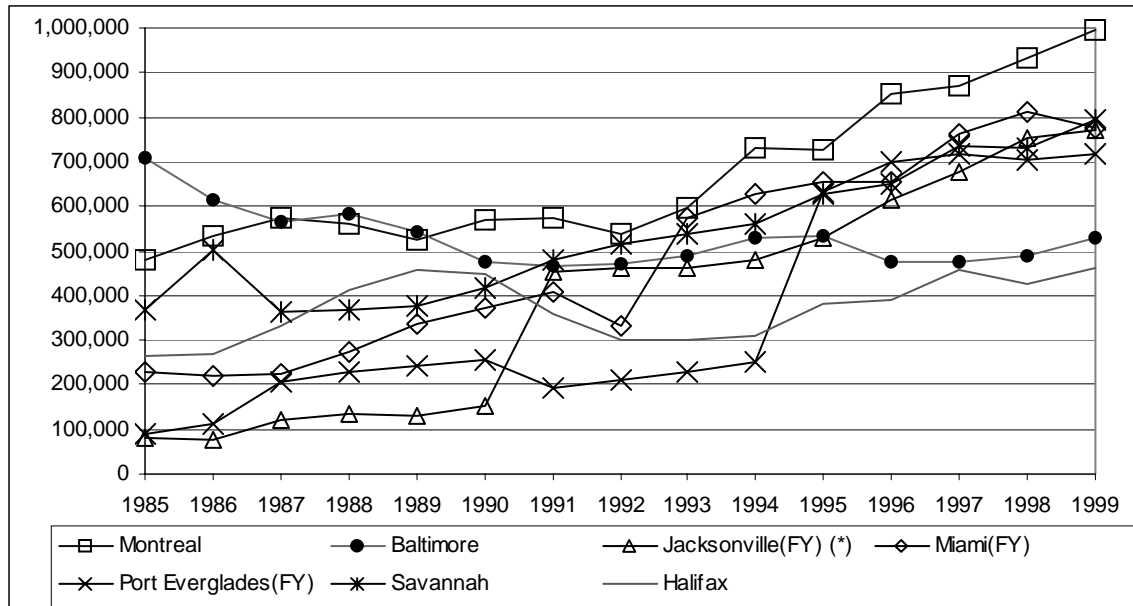


Source: American Association of Port Authorities. URL:
http://www.aapa-ports.org/pdf/US_Canada_Containers.PDF

Further increases in demand for East Coast container port services are anticipated as a result of (1) economic growth, (2) the expansion of container shipping from South and Southeast Asia (from Singapore, west) through the Suez Canal and Mediterranean and on to US and Canadian Atlantic ports (Ellis, 2000). Increases in demand for Atlantic Coast ports services also may occur due to (3) the possible increasing use of an all-water route

to the East Coast from Asia through the Panama Canal for non-time sensitive cargo (R. Sabonge, Panama Canal Authority, personal communication, 2001).

Figure I-3. Container Throughput for Major US East Coast Ports and Canadian Ports 1985-1999 (in TEUs)



Source: MARAD (2000)

To meet this anticipated growth, however, East Coast ports face major obstacles. These are exemplified at the PNYNJ, at Quonset Point, RI, and at Daniels Island, South Carolina (SC). The PNYNJ's plans to increase the depth of its channels and berths to expand port capacity have been frustrated by high costs (over a billion dollars) and substantial delays (potentially, 15 years) due to restrictions on dredging and lack of onshore disposal sites for dredged materials. Beyond these issues, severe highway congestion constrains additional movement of containers by truck from the PNYNJ to hinterland markets in the northeast, so that transshipment by barge is being pursued for non-time sensitive cargo (Moffatt and Nichol, 2001). In the case of Quonset Point, stakeholders concerns (largely, but not exclusively, environmental) caused cancellation of initial container port development plans at this Narragansett Bay site. Plans at Daniels Island, SC were substantially scaled back and perhaps cancelled due to concerns with additional trucking, the adequacy of existing roads, potential rail construction through a National Forest, and the need for substantial dredging.

Container port development takes place within a broad economic and policy setting involving many parties. National policy for the transportation sector fundamentally is concerned with supporting national economic efficiency (US Public Law 102-580, 1992; US Public Law 104-88, 1995). Efficiency can be understood to mean the development and operation of a linked, intermodal (port, ship, barge, truck, rail) system that maximizes the national economic benefits of moving goods from sources to markets, where the benefits and costs considered include environmental effects. However, development and operation of container facilities largely is left to the private sector, with promotion,

oversight, and often some financing provided by the states,¹ typically operating through port authorities. In contrast with the national viewpoint, state port authorities generally view terminals as “gateways” to hinterland markets and as “engines of economic growth”—in short, as a vehicle for state or regional economic development.

State governments, of course, have an important role in supporting programs that increase the well being of their citizens. This role is particularly important when the private sector, acting alone, would undertake projects in ways that are economically inefficient or otherwise socially undesirable. Container port development invariably raises many issues with potential external costs (and possible benefits), and port development often requires provision of many public goods/collective goods, including environmental studies and formal Environmental Impact Statements, mitigation measures, navigational aids, dredging of channels, highway improvements, overpasses, and monitoring and oversight. Hence, port development involves many potential sources of market failure. Public goods and collective goods typically are not adequately provided by the private sector since businesses capture little, if any, of the benefits that these goods provide. In such cases, collective actions are needed through government, interest groups, as well as the private sector to provide for, internalize, or otherwise avoid the unfavorable consequences of market failure.

A state’s goal of promoting economic growth through support of port development need not conflict with national goals of an efficient transportation system. However, conflicts between national and state goals can arise due to “spillover effects” and failure to consider substitutability and complementarity between ports. First, consider spillover effects. Local port planners may not fully consider important benefits from port development, such as transportation cost savings that fall outside state boundaries. Likewise, local port planners may not fully weigh costs imposed on other areas, such as contributions port activity may make to congestion, air pollution, or traffic delays at rail crossings perhaps many miles from the port.

Failure to account for (internalize) costs or benefits can create several problems. Understatement of benefits by a private investor or port authority may lead to a less than ideal (in the sense of maximum net benefits) level of investment from the national viewpoint. On the other hand, failure to consider offsite costs can lead to excessive investment compared to the level (or type) that would provide the largest economic benefits.

Second, conflicts between national and state policies also can arise if the benefits and costs of a potential port are assessed in isolation, without considering substitute or complementary effects among ports within a region. When ports are *substitutes*, such as when two ports vie for status as a hub port for a market area, an isolated assessment of the benefits of development at each port will *overstate* the combined economic benefits of

¹ To be sure, the federal government plays an important role in assessing environmental impacts, in approving rail mergers, and in partially financing authorized maintenance dredging and highway construction projects. Nevertheless, the impetus for port development and related offsite investments is from developers and states, the latter typically through port authorities.

the ports as compared to a consideration of both ports at the same time. This occurs because growth at one port comes at the expense of the other. Failure to take substitution into account creates the familiar problem noted in the literature that, when projects are inappropriately viewed in isolation, “too many projects pass the benefit-cost test” (Hoehn and Randall, 1989). In this case, too much investment in ports may occur. On the other hand, if ports are *complementary*, for example when one is a hub port and the other is a feeder port, then a separate assessment of the benefits of development at each port will *understate* the combined economic benefits of the ports.² In this case, too little investment may occur.

The consequences of the failure to consider substitutability among ports are: (1) excessive resources are committed to port activity, by that drawing scarce resources away from other worthwhile projects, and (2) overall environmental quality may be lower due to this excess development, unless avoided by design measures or through mitigation. These consequences will be exacerbated if proponents exaggerate economic benefits or underestimate environmental costs. And of course, the opposite occurs if opponents of port development understate benefits or overstate environmental costs. Failure to consider complementarity between ports leads to the opposite effects—too little investment. Whether and the degree to which ports are competitive or substitutes (or independent of each other) is an important empirical question. Our port demand simulation model (Chapter II) is designed to shed some quantitative light on these issues in later stages of our work.

Other, related issues arise from the highly competitive nature of container ports, particularly since the deregulation of trucking, railroads, and shipping. For example, large shipping lines are mobile and have (or can claim to have) flexibility in selecting ports in an effort to exert bargaining power when negotiating terminal fees with ports. This bargaining power is greater yet given the now-common trend toward formation of shipping line alliances and of mergers and acquisitions, all of which reduce the number of independent competitors. In such cases, terminal operators can be pushed for low rates with the promise of high volumes of container boxes through the port. And of course, ports compete with each other to lure away carriers from other ports — and then must compete with promises of lower fees to retain them.

The bargaining strength of alliances is further enhanced by the presence of *moral hazard*—the fact that shipping lines negotiating with a port will have information on terms offered by other ports, information that is unavailable to the port with which it is negotiating (the asymmetric information problem). In sum, terminal operators committed to paying off expensive investments in the face of what is, to some extent, a footloose industry often are in a poor bargaining position (the “holdup” problem (Tirole, 1988)). Different, but also important, bargaining issues also can and do arise with labor unions.

² Stated another way, suppose X and Y are competing (i.e., substitute) ports, and B(X) and B(Y) are the net benefits from proposed port development at locations X and Y, respectively. Failure to consider interdependencies between ports leads to a situation where $B(X) + B(Y) > B(X+Y)$, where B(X+Y) is the net benefit of two ports considered together. If ports are complementary, independent assessments of each port will understate total benefits, i.e., $B(X) + B(Y) < B(X+Y)$.

These problems, which collectively fall under the heading of strategic behavior and “rent seeking” are an increasingly important factor in influencing not only overall port profitability for the terminal operator but also the *distribution* of benefits and costs”³.

At the same time, port development is very expensive, demand is uncertain without adequate long-term shipping company contracts, and competition among ports is intense. This competition involves not only domestic ports, but also Canadian ports, most notably for the US East Coast, the ports of Halifax and Montreal (Figure I-2, Figure I-3). Further, environmental concerns often delay and restrict development and can be costly to address.

In summary, for all of the reasons mentioned above, considerable uncertainty exists about the profitability of port development, which can create risks for private operators. These factors also create much uncertainty for states and for national policy.

To be sure, operators of proposed terminal facing the rigors of the market have every incentive to control costs and reduce business risks and must comply with myriad and possibly changing environmental requirements. Further, states supporting port development will seek to address environmental issues through mitigation and public investment in intermodal access in order to avoid external costs and win public approval by convincing the public that overall benefits exceed costs. If optimistic expectations are met, port development can provide substantial net benefits in the aggregate, as we show for a hypothetical illustrative case in Chapter III. On the other hand, an operator’s or a state’s investment costs may prove to be higher than anticipated; activity through the port or fees received may be lower than expected; the costs of redesign, delays, and mitigation to address environmental issues may be higher than planned; and environmental costs and use conflicts (collectively--external costs) can be substantial even after mitigation⁴. If any or all of these developments transpire, then subsidies may be required, then net benefits may be smaller than anticipated (conceivably requiring a subsidy), and the original purpose of the proposed development—to improve the well being of state residents--is undermined (See Chapter III).

In summary, container port development at the dawn of the twenty first century raises major, and perhaps unprecedented, issues for terminal operators, port authorities, the public, and other stakeholders. These issues include the implications of broad, emerging trade patterns; technological and structural changes in container shipping and ports; the economic feasibility of individual port development plans; evaluation of environmental issues and their resolution; a state’s versus an operator’s (or railroad’s) role in the financing of port development; potential conflicts between national and state objectives, and issues of strategic behavior and rent seeking by different parties. All of these factors can and do impinge upon port feasibility, the distribution of benefits and costs, the quality

³ Rent seeking occurs when actions by an interest group *divert* economic benefits from others to themselves (e.g., through import quotas, rent control, subsidies, or union activity). Rent seeking thus differs from profit seeking, which involves *expanding* economic benefits (Buchanan). Thus, profit seeking expands the “economic pie” while rent seeking concerns how the pie is divided among groups.

⁴ Most recently, national security has become an additional issue posing risks for transportation systems.

of the environment for affected areas, and the efficacy of the national transportation system.

In light of the high stakes involved with port development, the considerable uncertainties surrounding issues at virtually every level, and the inherent difficulties in addressing most issues, there is a need for objective, analytical studies of container port development that can contribute to public discussion and policy. To be most useful, such studies should be cross-cutting, integrating key financial, economic, environmental, and strategic factors within a unified and consistent analytical framework.

I. B. PURPOSE AND SCOPE OF THE YEAR ONE RESEARCH AND OF THE OVERALL PROJECT

I. B.1. Overview of Framework and Study Goals

This report summarizes the *year-one results* of research conducted at the University of Rhode Island (URI) on container port issues, focusing on the US East Coast. The long-run goal of the project is to develop what we refer to as a “comprehensive framework” for assessing container port development on the US East Coast.

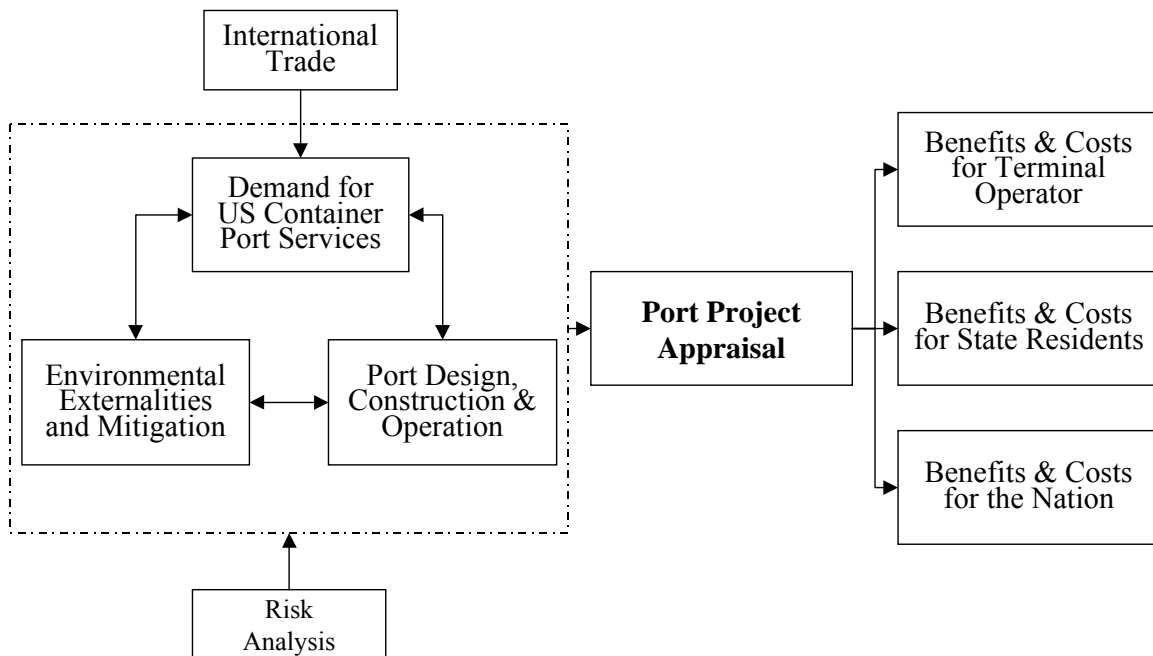
A “comprehensive” framework is needed due to the interplay of the many financial, economic, environmental, strategic, and other issues involved with container port decisions. By “framework”, we mean the use of a set of integrated concepts and methods for organizing and analyzing information in order to understand better complicated and inter-related container port development issues. The practical meaning of these seemingly abstract ideas will become clear as we proceed.

The overall framework (Figure I-4) incorporates (1) international trade (imports to and exports from US regions); (2) the associated derived demand for container port and intermodal transportation services in the US; (3) port (terminal) development and its feasibility; and (4) environmental issues. Uncertainty and risk are common and notable features of all elements of this framework.

Of course, the broad framework set out in Figure I-4 suggests only the bare bones structure of the project; detailed and extensive analyses are needed to flesh out the framework. In the Chapters that follow, we present the concepts, methodology, and data to be used to eventually make the framework operational, and we also illustrate parts of the framework through examples and case studies.

The framework, and the concepts and models used to implement the framework, are not an end to themselves. Rather, they are a means to an end, which is *to provide objective information on benefits and costs that can contribute to difficult and important container port decisions*. Reflecting the underlying economic focus of our work, all of the analyses are directed toward deriving estimates of the *incremental* benefits and costs of proposed container port development.

Figure I-4. Simplified Depiction of Comprehensive Framework for Container Port Development for US East Coast



This focus raises the important question: Benefits and costs to *whom*? Port development poses major issues for prospective terminal operators and for state and national policy, as pointed out earlier. For this reason, benefits and costs in our framework are assessed from three different perspectives: (1) a private container terminal operator (assumed to be an out-of-state operator), (2) current residents of a state, and (3) the nation. We define these entities and relevant benefits and costs more carefully later, but at this point the net benefits to each group can be (loosely) described as follows:

- A *private terminal operator* maximizes the net present value (NPV^O) of its investment (Chapter III). Terminal operators are primarily concerned with narrow financial flows (“private profitability”), but may bear the costs of complying with environmental regulations and of design changes or mitigation measures to avoid or offset potential environmental costs. The estimate of NPV^O represents the economic value of the investment to the operator and is the most a prospective terminal operator would pay above investment and operating costs for the right to develop and operate the facility.
- *Current residents of a state* are presumed to be interested in maximizing the net present value (NPV^{SR}) of port development to them (Chapter V). NPV^{SR} is broadly defined at this point to include transportation costs savings to residents, increased income to resident

workers (i.e., the amount they receive over the next best use of their time), net environmental effects, net fiscal effects, and net offsite investment and operating costs borne by current residents, plus benefits these investments provide to residents. The NPV^{SR} , in principle, is the most current residents collectively would pay for a proposed port development.

- From the *national* perspective, the net benefits of port development are transportation cost savings, net of any environmental improvements (Chapter V), and increased income to workers (i.e., the amount they receive over the next best use of their time). All other effects of a port (e.g., taxes and fees; relocation effects) are a wash in that they will be largely the same wherever a container port is located. In principle, the NPV^N is the maximum the nation would pay for a port development.

Below we outline the key elements of our framework. We note important links between gains and costs to different groups. For example, a fee on terminal TEU throughput that is paid to the state (i.e., a Port Authority) increases benefits to state residents, but at the same time raises costs for state users of the port. Any state subsidies for investment or operating costs increase an operator's profitability but reduce net benefits to state residents. On the other hand, costs incurred by the state for offsite investment, such as construction of an overpass or road improvements, represent at least in part a cost to state residents, but will lower delivery costs for port users and may benefit state residents who use the overpass or road for personal use.

In sum, we look at benefits and costs to three entities: (1) a private, out-of-state terminal operator, (2) current state residents, and (3) the nation. This will allow us to sort out how the benefits and costs of port development get distributed among the different parties. A detailed discussion of these and related issues is given in the Chapters that follow.

I. B. 2. Container Port Demand Simulation Model (Chapter II)

Demand for container port services is derived from the demand for imports and exports of containerized goods. At the *aggregate* level, US demand for imported containerized goods is a function of domestic income, population, and other factors influencing demand, such as exchange rates. Demand for containerized exports depends upon economic activity in other countries, exchange rates, and other factors. The *geographic pattern* of US demand for container port services depends upon (1) the location of domestic consumers with respect to foreign sources, for imports; (2) the location of manufacturers, farms, resource industries, and other exporting businesses relative to foreign markets for their goods, and (3) the availability and relative costs of intermodal transport from sources to markets.

A least-cost path *container port demand simulation model* provides the empirical approach we will use to estimate demand for US container port services. Briefly, the model solves for the minimum cost of moving containerized cargo from sources to markets in order to meet given market demands. Costs include intermodal transportation costs, plus the interest cost on the investment tied up in the value of goods being moved. To implement the simulation model, trade at this point is taken to be exogenous—i.e., fixed at the 1999 level⁵.

For the US, imports and exports are analyzed at the state level, although for the Northeast US the model will be applied at the *county* level. Intermodal options (vessels, road, and rail) are included in the model. International sources (for US imports) and markets (for US exports) at this stage of our research are aggregated into continents (Asia-two regions, Europe, etc.). Commodities are analyzed at the two-digit Standard Industrial Classification level. Further geographic and commodity disaggregation are anticipated in later phases of this project.

Within the container port simulation model, demand for container port services at individual ports depends upon the location of the port with respect to sources and markets and on intermodal costs. Any model at the national and international level necessarily must rest on simplifying assumptions, especially at an early stage of analysis, but can be expanded and refined over time. Such a model could be used to simulate the consequences for port use of many potential policy-relevant changes. For example, it could be used to assess US demographic changes over time, which might affect the comparative advantage of certain ports. The effects on demand for port services of changes in environmental policies (e.g., on air emissions from trucks), changes in energy costs, or transportation system disruptions also might be assessed using the model.

Given the results of the container port transportation demand simulation model, our goal is to include a hypothetical new port in the multimodal transportation network. If the intermodal costs of moving containers through the port are less than alternative routes, the model will indicate shipments through the port. To apply the model, representative port fees and costs for intermodal movements will be used, and the model objective will be to minimize total costs of moving containerized goods to meet given market demands at the state (or county, for the Northeast) geographic market level. The model should reflect substitution effects, i.e., the fact that a new port would lead to less activity at other, competing container ports. Hence, the model can be used to get insights into the potential importance of substitution effects and of potential competition and strategic behavior among ports.

To focus better on a case study port, and on issues of the environment, competition, and strategic behavior for our port case study, a much more detailed geographic resolution will be used for the Northeast, as noted. For this purpose, a detailed cargo generation or destination places model of the northeast container market is being developed, an area preliminarily extending from New York/New Jersey to Maine. For this area, we are

⁵ In our Year Two URITC project, we are attempting to develop an econometric forecasting model for demand for container shipments through US ports.

assembling extensive information on the intermodal transportation network, including national highways, railways, inland container terminals and even local roads.

The model also could be used to examine net environmental effects from a multi-port or regional perspective. For example, while port development could create some external costs, it may also result in offsetting environmental benefits which should be considered. For instance, if movements of containers through a new port substitute for some trucking of containers through the area from other ports, the offsetting effect of reduced vehicle miles should be recognized. Our detailed, container port simulation model could show this.

I.B. 3. Port Feasibility Model (Chapter III)

A discounted cash-flow (DCF) model is used to assess port profitability (net present value) and to analyze uncertainty and risk associated with port investment decisions. Given the many sources of uncertainty (e.g., startup volume and growth, efficiency, costs) involved with any port proposal, sensitivity (“What if?”) analysis and Monte Carlo Simulation can be valuable tools for showing alternative outcomes and the chance of a gain or loss. Also, a dynamic, discrete event analysis (explained in more detail in Chapter III) is used to examine aspects of internal consistency of port development design for a case study, and hence represents another kind of risk analysis.

The port feasibility analysis framework provides a key building block for the overall study. This is because operator decisions on the scale and nature of the development and intermodal decisions affect net benefits to state residents (e.g., transport cost savings, net fees, net increases in labor income, and environmental costs) and to the nation (transportation savings, net increases in labor income, and environmental costs).

An initial and very preliminary assessment of port feasibility and risk was undertaken, using as an illustrative case study readily available data for a port proposed for Quonset Point, Rhode Island. This choice was natural, given (1) the proximity of the site and availability of much information on the surrounding area and on the proposed project and (2) the intense interest (albeit from different perspectives) in a potential port at the site.

We do not have sufficient confidence in any study done to date to rely exclusively upon it for our case study. Instead, we draw information from several sources and stress to readers that we are merely *illustrating* an element of our framework—not providing a judgment, legitimization, or endorsement of any study or port proposal done to date. As additional information becomes available for our case study site (or another case study site), our port feasibility case study can be revised, as appropriate. Meanwhile, the model itself provides a tool that users (at a later point) could employ to examine how their own assumptions about a port would affect its feasibility.

I.B.4. Environmental Externalities (Chapter IV)

Potential environmental externalities from port development are a major factor in port decisions throughout the US. Environmental concerns can require modifications in port plans, delay projects, and require expensive mitigation measures—and often all three.

We present a *generic* review of potential environmental costs. The framework stresses assessment of *incremental* external effects, and recognizes the many challenges in carrying out such analyses, particularly in attempting to convert non-market environmental issues to monetary measures. Quantification of environmental effects in monetary terms is important, we argue, in that it (1) allows for an objective assessment of the relative importance of each, (2) can contribute to decisions on mitigation measures, and (3) can aid in improving the overall assessment of the *net* benefits from port development. Without an objective assessment of environment costs, the danger is that all costs will be viewed as “major” and no reasoned basis will exist for distinguishing between potential serious costs (and their possible mitigation) and less serious or minor issues.

Selected examples of potential external costs are used to illustrate the issues involved, standard valuation methodologies that are available to assess these issues, and example results for different types of potential environmental costs associated with port development. We show that valuation methods, though imperfect, can provide useful information for policy purposes. We also show that uncertainty and risk are as important for environmental issues as they are for purely financial issues.

I.B.5. Social Benefits-Cost Analysis: Framework and Examples (Chapter V)

The analysis of port investment feasibility (Chapter III) primarily involves narrow, financial concerns—i.e., private benefit-cost analysis or “private profitability”. Use of an investment appraisal model to assess a proposed port gives important insights into the feasibility and possible scale of activity, and perhaps the nature of certain operations. Investigation of private profitability also establishes a key building block for assessing broader issues involving economic benefits and costs, including environmental costs, and the distribution of benefits and costs over various parties.

In contrast with the private profitability, social benefit-cost analysis is much broader and uses standard benefit-cost analysis principles to assess all benefits and costs, not just financial flows. We include in our framework an assessment of social benefits and costs (“social profitability”) from two perspectives: (1) the nation as a whole, and (2) the state (which could be a broader region in some cases) in which a port is located.

As noted earlier, the major goal of *national* transportation policy (simply stated) is the economic efficiency of the national transportation system. National economic benefits are measured as the incremental savings in transportation costs to whomever they accrue, plus net increases in income to workers (payments in access of the value of their time in alternative uses) and any net benefits due to reduced environmental costs.

For states, the net benefits of port development are more complicated. State benefits include transportation cost savings to residents and net gains to resident labor, to the extent resident workers are paid more than the value of their time in its next-best use (other employment, work at home, recreation and leisure). Gains to labor, generally speaking, depend upon the unemployment rate, but in any case are substantially less than gross wages paid by business since all workers have an opportunity cost.

Costs include potential environmental externalities, which are important since state residents likely bear most environmental costs, although design measures and mitigation can reduce or eliminate many of these costs. Further, offsetting environmental effects must be recognized, if for example, environmental costs due to trucking (congestion, air pollution, possibly noise) are reduced in part by a port, for example. Net fiscal benefits also could arise at the state level, if the fee states collect on containers destined for markets outside the state exceed the any offsite costs states incur and the costs states must bear in monitoring and administering ports through Port Authorities.

We measure state benefits and costs from the viewpoint of *current residents*, who must make decisions on whether and how to accommodate port development and accept the consequences. Traditionally, state-level effects are based on “impact analyses”, which typically summarize gross revenues, wages, taxes and other information and use naïve multipliers. However, impact studies run the risk of ignoring potentially important benefits (transportation cost savings) and grossly overstating other benefits. Particularly serious problems arise when impact analyses fail to include the value of alternative uses of resources devoted to port activity.

We include in state benefits transportation cost savings, environmental externalities, net gains to labor (versus gross wages paid), and other market and non-market effects. Thus, social profitability attempts to assess the overall net benefits to an area from a project – the benefits with the project versus those without the project. Clearly, social profitability is much more difficult to assess as it involves not only financial flows but also potential external costs and benefits that are not valued in markets. Nevertheless, such an analysis is key for understanding the economic consequences of port development for state residents. Throughout this report, we focus on the *incremental effects* of port development and examine *net* benefits and costs for state residents, that is, the effects with the port as compared to effects without the port.

Given the ambitious scope and scale of this project, a multi-year effort is required for full implementation. Our work is made possible only by a truly fortuitous combination of circumstances. These include support of the project by the new *URI Transportation Center*, funded by the US Department of Transportation; close collaboration with and matching support for the project through the *Korea-America Joint Marine Policy Center* at the University (funded by the Korea Maritime Institute), the existence of which made available considerable expertise in shipping, ports, and operations research to complement expertise in environmental economics; and the advent of a state-of-the-art, Policy Simulation Lab at the newly-constructed, federally-funded Coastal Institute on the main campus at URI in Kingston.

We also recognize that even solid technical analyses may be of limited use if the analysis and results are not presented in ways that engage interested parties. To make the results accessible to readers, when possible we adopt a non-technical style directed toward well-informed members of the public, interest groups, the business community, and those in decision-making positions. We also have sought to make clear our assumptions and judgments and to explain important sources of uncertainty. This is done so that the reader can better appreciate the confidence they can have in the results. It also makes clear to the reader the many instances where the results are only illustrative or preliminary and need to be refined or expanded.

To enhance the usefulness of this work, our ultimate goal is to extend the research results from this project into a Decision Support System. To achieve this long-run objective, we propose to use the state-of-the-art Policy Simulation Lab in the Department of Environmental and Natural Resource Economics at URI's new main campus Coastal Institute (Opaluch, 2000). We envision the Lab as a novel facility that will encourage use by the public, business community, and government officials. It will make available modern, multi-media methods to visualize alternative, potential developments. More importantly, the Lab will enable users to carry out "what if" analyses, tracing out the consequences of important resource-use decisions, such as those associated with a proposed container port. Efforts to move our research results into the Lab will be done in the final phases of our research.

I. C. ORGANIZATION OF THIS REPORT

Chapter II puts port development issues into context by recognizing that the demand for port services fundamentally is a derived demand and depends upon the flow of goods to and from the US in international trade. We present a container port demand ("market") simulation model and explain the assumptions, rationale, and potential uses of this model. We also briefly note planned extensions, including a planned forecast of international container trade trends, an important concern since future demand for port services depends upon the scale, composition and geographical pattern of exports and imports.

Chapter III focuses on private (or operator) benefit-cost analysis ("private profitability") and presents an *illustrative* (i.e. stylized) investment appraisal and risk analysis for the case study port proposed for Quonset Point, RI. Concepts are introduced, the major assumptions, features, and costs of the proposed port alternatives are outlined, and the estimates of financial feasibility (net present value) are given. Extensive sensitivity analyses and more formal Monte Carlo and other analyses (explained later) are used to examine how the results would change if certain assumption underlying the projected port activity, cost, or other factors in the analysis are varied or optimistic assumptions are not met.

Chapter IV reviews environmental issues potentially associated with container port development. First, a *generic* discussion of external costs potentially associated with port

development is given. The importance of quantifying these costs is explained, as are the many challenges faced. Then, several examples are used to illustrate how different types of external costs due to port development can be estimated and used to give a perspective on the potential external costs of port development and of potential mitigation or design measures that might reduce or eliminate some external costs.

It was *not* the purpose of our Year One research to thoroughly assess all aspects of the case study port under consideration for Quonset. The discussion in Chapter V is intended (1) to present key concepts that will be eventually integrated and applied in later phases of our work, and (2) to provide illustrative applications of concepts and methodologies to particular benefits and costs.

Chapter V pulls together the analyses in prior sections to focus on social benefit-cost analysis (“social profitability”) – who benefits and who pays and how much? Key elements of social benefits and costs of port development to be addressed in planned future research are examined. The underlying principles of benefit-cost analysis are explained. Considerable attention is given to the critical role of net benefits and opportunity costs, particularly for improving estimates of gains workers receive with port development.

We assess benefits and costs to the nation, the primary concern of national transportation policy. However, we also focus on benefits and costs at the state level (state residents) as port development is a major issue for states, and a proper analysis of these issues – which differ from a national focus – can provide useful information on costs and benefits for decisions at the state level.

I. D. THE RESEARCH TEAM AND FINANCIAL SUPPORT

Funding for this research is a joint effort between the new URI Transportation Center (URITC) and the *Korea-America Joint Marine Policy Joint Research Center* (the *Center*) at the University of Rhode Island (Center Paper # 01 – 08). Additional support comes from the Department of Environmental and Natural Resource Economics (ENRE) and the Agricultural Experiment Station at URI. (AES Contrib. # 3906)

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We also acknowledge, again, many very helpful comments, on an earlier draft, by Dr. Richard Horn Executive Director of the URI Transportation Center and by an anonymous reviewer. Useful comments also were provided by Professor James Opaluch and Assistant Professor Christopher Anderson. Any remaining errors are those of the authors.

II. CONTAINER TRANSPORTATION DEMAND SIMULATION MODEL FOR US COASTAL CONTAINER PORTS

II. A. Introduction

Demand for container port transportation services plays a central role in our comprehensive framework. For example, any assessment of the potential economic feasibility and net economic benefits (transport cost savings and net environmental effects) from port development requires a prediction of the potential container moves through a proposed port. This prediction must be based on an estimate of container port transportation service demand.

This chapter explains the model we are developing to estimate container port transportation demand. First, we have to clarify the concepts of demand for container port services and container throughput. The market for container port services, like all markets, has two basic underlying forces – demand for such services and their supply. The demand for such services is derived from international trade of containerized commodities, which depends upon the cost for using port services and its quality, among many other things. The supply is the quantity and quality of service a container port is willing to provide, contingent on the payment it can receive from the user. In theory, it is the equilibrium of these two forces that determines the throughput of a container port.

At the most basic level, the demand for container moves through a port will depend upon fees for using that port, and the characteristics or attributes of the port. More generally, the demand for container port services is a derived demand from international trade of containerized cargo, and is affected by world economic developments, exchanges rates, container shipping competition, port competition (including port fees, intermodal access and fees, and distances), business practices, and strategic behavior. In short, the demand for container transportation services at a port, and competition between ports, is the result of many different factors and clearly is a complex and dynamic issue.

Predictions of port demand can be based on an implicit or explicit analysis, and can make use of an informal (e.g., expert judgments, extrapolation of trends, use of scenarios, user surveys) or a formal model, such as an econometric or simulation model (Murphy 1992, Tsamboulas *et al*, 2000). Expert judgment and other “informal” methods are relatively simple, inexpensive, and can be done quickly. These are important advantages. However, such informal approaches may not allow third parties to understand the relative importance of the key factors and assumptions relied upon, and how estimates of demand might change if any or all of the underlying assumptions change. Further, informal judgments do not allow for development and tests of hypotheses. Additionally, approaches based on informal judgments may not lend themselves to estimating systematically the economic benefits from port development or other changes in ways that are consistent with economic behavior and theory. Clearly, prediction of demand is complex, depends on many factors, and uncertainty is a major concern.

We are developing a simulation model to estimate demand for container transportation services at US coastal ports, which we view as a potentially important *complement* to other approaches for estimating the demand for container port transportation services. Mindful of the many difficulties involved with estimation of demand for container port transportation services, we are not wedded to total reliance on any single approach. Below, this simulation effort is described in somewhat general terms; a formal, basic model is given in an Appendix to this chapter, for those interested in the details of this approach.

A simulation model to estimate demand for container port transportation services offers several potential advantages. For one thing, a good model (one that reasonably mimics current container movements using fundamental economic variables) can be used to help assess the potential demand for a new port, and it can specifically incorporate possible, important substitution effects due to competition and strategic behavior between ports. Further, a simulation model can provide important insights into the potential consequences for container port demand of different external developments or policies affecting ports, for example, higher energy costs, changes in environmental regulations, new sources of imported goods, or temporary disruptions in supply or routes.

In short, a successful simulation model can contribute to our overall objectives of better understanding the net benefits to a terminal operator, to state residents, and to the nation due to container transportation port development. If the model has enough detail to include such issues as changes in vehicle (truck) miles in an area due to port development, it also will be possible to link some environmental issues (e.g., traffic and net air pollution emissions) with the results of the simulation model. Of course, development of a simulation model on the scale envisioned here is an ambitious and complex effort, demands considerable data, and requires use of many simplifying assumptions, especially at the outset. Again, we recognize the many challenges involved, and are aware that as in all complicated efforts, progress in simulating the demand for container port services must be made in stages.

II. B. MODEL EXPLANATION AND ASSUMPTIONS

Our model attempts to simulate the container transportation process. To this end, we assume that shippers seek to minimize the total cost of delivering goods from sources to markets, considering the whole transportation network. We seek to solve this least-cost transportation problem for a base year: 1999. The model takes as givens trade flows between sources (initially, outside the US we focus on continents, with Asia divided into two regions) and markets (for now, states at the national level and counties for the northeast), transportation facilities, and their unit costs.

To make this modeling practical, we start with many simplifying assumptions, taking many of the factors affecting transportation demand (e.g., international trade, inter-modal facilities, and costs) as exogenous or givens. These assumptions allow us to concentrate on examining selected, fundamental factors affecting the demand for container

transportation service at ports. We leave open the possibility of expanding this work at a later point, allowing us to include factors now assumed exogenous to be incorporated in the simulation process as sub-modules.

Our simulation model is viewed as a first step in modeling container transportation service demand at US ports. As such, the model at this point concentrates on only two key issues in port demand estimation: (1) individual shipper's route choices for different cargo categories, and (2) competition among ports. Thus, at this stage we put aside the effects of many other factors influencing the demand for port services by making a series of assumptions concerning international trade, shipping, port supply and efficiency, and individual shipper's behavior. Below we explain the assumptions employed and give the rationale for and implications of these assumptions.

II. B. 1. Assumptions on international trade

U.S. container port services are a derived demand from international trade, which determines the overall amount of cargoes transported into and out of US coastal ports in containers. Uneven development in world production and consumption, world currency market fluctuations, and other factors influence the quantity of international trade of various cargoes and as a result, affect the demand for port container services.

We take the quantity of trade as given in our port simulation model. For one thing, development of new container port facilities will have a minimal effect on overall international trade since terminal costs are a small share of overall commodity production and transportation costs, and new facilities likely will lead to only a very small decrease in overall costs (in most cases, no more than a few percent of the final price). Thus, it is reasonable to assume international trade is exogenous to our simulation, so we can take current international trade movements as a given.

In the long run, however, trade will expand due to economic growth and other factors, and it is important to consider the implications of this growth for the demand for US port services. Thus, as a long-run goal, we plan to relax the assumption that international trade is a fixed amount¹. This would improve our model by incorporating an international trade sub-module in the container port demand simulation, but is a very large undertaking and much beyond the scope of this Year One report. Until such a trade model is developed, simple applications might consider (1) changes in demand for port services when overall trade grows at a certain rate or (2) cases where trade in different commodities, or to and from different areas, grow at different rates, or where energy costs change, and so forth.

¹ As part of our Year Two URITC project, we are developing an econometric model in order to forecast trends in demand for container movements.

II. B. 2. Assumptions on maritime transportation

Important factors in maritime transportation include shipping line deployment and scheduling, liner shipping economics for different container vessel sizes, market competition among shipping companies, and non-liner operation of containerized vessels, etc. Since our purpose is to simulate *annual* container port transportation demand and our waterborne trade data is aggregated annual data, our model uses average values for factors of interest, such as average vessel speed on a route and the average freight rate.

Besides, different companies have different strategies for shipping line deployment, so we can assume that on average there are direct shipping line services to and from each major US port for each continent. This assumption enables the model to use geographical information about the location of each major U.S. port with respect to world continents to construct a simplified international shipping route in the intermodal container transportation network, and calculate the shipping cost according to the length of the shipping route, average unit cost per mile, and average vessel speed.

Relaxation of this assumption on marine transportation would require a complete database for all shipping lines that call at each major port, for all vessel sizes and operation economics, as well as scheduling and load factors. Then, the annual database on waterborne trade, used in our current model, would have to be replaced with more detailed data, perhaps daily data. This detailed level of simulation may be very important for studying individual shipping line operations, but does not necessarily provide for much improvement for our purposes.

II. B. 3. Assumptions on port supply and efficiency

Many different payment arrangements exist among port authorities, terminal operators, and the shipping lines that use terminal facilities. There are detailed, itemized cost structures for the use of terminal facilities and for use of ports, which differ from port to port, and differ even from terminal to terminal within a port. Also, the actual payment structure may not be (likely is not) the same as the public tariff system. Therefore, to simplify the simulation process, it is necessary to make some simplifying assumptions about port costs.

On the other hand, the amount of containers using a particular port is conditional on the charges, efficiency, and reliability of that port as compared to competing ports. To simulate the number of containers that will move through that port (demand), our model uses port terminal charges to represent the market price for using that port. We will also use the average number of days a container is expected to stay in terminal facility as an indicator of port efficiency.

Port capacity constraints are another, complicated issue. Generally speaking, capacity is an economic/engineering concept and can be viewed as the difference between the design

capacity of the port and its demand. In the short run, only limited ways are available to change capacity, but in the long run, new technology and operational procedures can substantially expand capacity. In our model, we will use an index for capacity, tying it to port-specific judgments of capacity relative to current use.

II. B. 4. Assumptions on individual behavior in transportation decision

In practice, firms that import and export containerized cargoes may not select the transportation route themselves. Instead, specialized agents (freight forwarders) provide this service for both consumers of the transportation service (shippers) and transportation facility providers (rail, truck, and shipping companies).

In order to avoid involving these intermediate agents in the simulation process, it is reasonable to assume that they are Irrelevant Intermediate Alternatives (IIA). Therefore, our simulation model assumes independent, individual firms select their own route of transportation for which costs are minimized in the transportation process. In this way, we do not have need to include each specific agent group in the model.

Other business operating practices regarding cargo import and export should be noted. For example, just in time (JIT) delivery requires that the cargo be delivered at the exact time when the customer needs it, by that avoiding storage costs and interest on the value of the investment tied up in inventory. This practice actually need not contradict the least-cost assumption used for our model. When JIT delivery does not incur additional cost, it is obvious that the least-cost route selection method is correct. If JIT delivery incurs an extra cost, then it gives the shipper the opportunity to reduce export or import cost by rearranging the production and delivery time. Doing so allows the shipper to select both the route with minimum cost *and* meet the time of delivery.

II. C. MODEL DESCRIPTION

Based on the previous discussion of the overall purpose and assumptions used in the simulation model, we next explain the reasoning or logic underlying the simulation model. A more rigorous, basic mathematical description of the model is given in an Appendix.

II. C. 1. Logic of the simulation model

In principle, many routes can be used to transport a container from a source in the US to a market in a foreign country or vice versa. Some routes may use more water transportation and less land transportation. The transportation cost for such a route selection is low, but a longer time is needed to reach the destination. Other routes use shorter sea transportation routes but longer land transportation (combined truck and rail), so the transportation cost is higher, but it takes less time for the cargo to reach its destination. Also, for the transportation process that uses more shipping, while there are

savings in a lower freight rate, the longer time required means that there will be a higher opportunity cost of capital tied up in cargo, higher depreciation cost for some cargo, and higher refrigerated container (“refer”) rental cost for cargoes (e.g., meat and fish) that need to be frozen during transportation.

Therefore, a trade off exists between the transportation cost and the time cost in the route selection decision. The individual will select the route that minimizes the total cost in the transportation process from the origin to the destination, where total cost includes the freight rate paid to the transportation facility provider according to usage, and the interest cost that varies with the time necessary for completing the transportation and cargo value. Each route is assumed to use only one coastal port. By selecting a least-cost route, the port that a typical cargo will go through is also determined. The aggregation of all containers that go through that port gives the simulated container transportation demand of that port.

II. D. IMPLEMENTATION

The implementation of this simulation model is based on a review of existing transportation models and their applicability in solving our problem. Next is a brief introduction to, and review of, the existing transportation models and available literature about port demand prediction. The main purpose of this review is to assess their applicability for our problem.

II. D. 1. Review on Existing Transportation Demand Models and Their Applicability

The most common method used in estimation of port container transportation demand is the demarcation of port hinterland area. Since it is only based on geographical location, and does not involve rigorous modeling efforts, it might be more appropriate to introduce first, separate from the others. This method takes the geographical area within certain radius of the port as the market area of the port. All the containers generated and terminated within this region are considered as the demand of the port. Because of its simplicity, it is perhaps the most frequently used method. However, it fails to take the export destination and import origin into account, and it also cannot take into account the effect of multimodal transportation. Therefore, even though this method has some popularity in application, it cannot be applied to our work.

Transportation demand is a major factor in transportation facility development and policy; therefore, many transportation models have been developed in transportation research. Generally, there are four different categories of transportation demand models: (1) trip generation models, (2) trip distribution models, (3) mode choice models, and (4) trip assignment models. An overview of each of them is given next, including a discussion of their applicability in our work.

II. D.1. a. *Trip Generation Model*

Trip generation models are used to predict the total number of trips produced or attracted by a zone. It takes the number of trips produced (P_i) (or attracted, A_i) by certain area, and attempts to explain this number using cross section regression analysis with predictive factors (z_{ij}) for that zone. A general form of the trip generation model is:

$$P_i = f(z_{i1}, z_{i2}, \dots, z_{ij}) + \varepsilon_i$$

This method could be used to model international trade of typical US region for different cargo categories. As mentioned above, in our simulation model we take international trade as an exogenous factor. So, we will not use this model in our research.

II. D. 1. b. *Trip Distribution Model*

Trip distribution models are intended to predict zone-to-zone trip interchanges. The final product is a projected origin-destination matrix of the form as show below:

Origin Zone	Destination Zone				
	1	2	3	4	...
1	T_{11}	T_{12}	T_{13}	T_{14}	...
2	T_{21}	T_{22}	T_{23}	T_{24}	...
3	T_{31}	T_{32}	T_{33}	T_{34}	...
4	T_{41}	T_{42}	T_{43}	T_{44}	...
:	:	:	:	:	:

Where T_{ij} refers to the number of trips with origins in zone i and destinations in zone j . The most popular model belonging to this category is the gravity model. The general form of a gravity model:

$$T_{ij} = \frac{P_i (A_j F_{ij})}{\sum_j (A_j F_{ij})} \quad \text{or} \quad T_{ij} = \frac{A_j (P_i F_{ij})}{\sum_i (P_i F_{ij})}$$

Where P_i and A_j are production from zone i and attraction of zone j respectively. F_{ij} is the impedance of travel from zone i to zone j , measured as the time or cost for that trip.

Again, this model just concerns the *number* of trips between two zones. It does not help in route selection for these trips. Therefore, we cannot use this in our work.

II. D. 1. c. *Mode Choice Model*

Mode choice models are potential candidates for port container transportation demand modeling. These models first assume that the utility of the entity planning the trip is

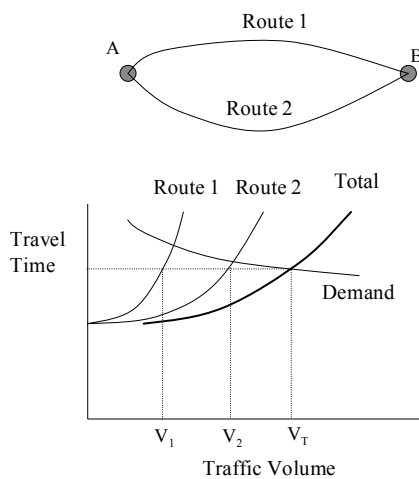
dependent on the mode-specific parameter and the set of travel characteristics of mode m , such as time or money costs, i.e.,

$$u_m = \beta_m + \sum_j \alpha_j z_{mj} + \varepsilon$$

where u_m is the utility of mode m , β_m is the mode specific parameter, z_{mj} is a set of attribute of mode m , α is the marginal contribution of that attribute to utility and is estimated through regression process. The most common assumption of the error term is the Weibull distribution, which resulted in *multinomial logit* demand model. If we assume normal distribution, it is then the *probit* model. The application of such a model is presented in Winston (1997).

This model can be extended to select the transportation route but applying this kind of model requires a huge and detailed data set for regression analysis. For example, assume we divide the US into 10 major sub regions, select only 10 coastal ports, for 10 different cargoes and export/import with 5 different continents in the world. We would need to obtain 10 statistical equations for each one of the 10 sub regions for each cargo category of trade with each continent. We would then need $10 \times 10 \times 10 \times 5 = 5000$ statistical equations. Also, this method requires observations on which port was used for different containerized cargoes transported between US inland area and foreign country. Even if it is possible to get these data for existing ports, and to estimate a statistical equation for each port, it is still impossible to predict the demand for a new port if the substitution effects of the new port on the existing port need to be considered.²

II. D. 1. d. Trip Assignment Model



Traffic assignment models predict the number of travelers using various routes. If the modeling objects are vehicles, then it is the traffic assignment model. The general idea of the model can be illustrated using the next two figures. The top figure shows there are two possible routes between place A and place B. The objective is to minimize the time to move total number of vehicles V_T from A to B by assigning the number of vehicles to Route 1 and Route 2.

This bottom figure shows if the traffic demand between two points is known and the travel supply (in terms of time, instead of the cost as in a normal supply function)

² Out-of-sample prediction requires that the predicted sample is independent of the data sample used for regression. In our case, we cannot assume that the outcome of the new port is independent from the outcomes from the existing ones. Actually, we want to know the impact of the new port on the existing port. Therefore, we cannot use this method.

of each individual route is also known, then the assignment of the trip will lead to an overall equilibrium. This is known as Wardrop's first principle (Banks, 1998), which could be restated as: *at equilibrium, no user can improve the trip time by unilaterally changing routes.*

This method is very useful in traffic control in maintaining smooth traffic flow between every two nodes in the whole transportation network. It may also be useful in our model if we want to take traffic congestion factors into account. However, since our purpose is to estimate annual transportation demand from annual transportation statistics, we cannot use this approach because it requires the use of detail traffic flow data between any two nodes.

II. D. 1. e. Other methods for transportation demand analysis.

There are also other more rigorous transportation demand models, like the traditional Warehouse-distribution model (Hillier & Lieberman, 1973) that deals with optimization on quantity of cargoes to be transported between warehouse and market area. Most of these models are developed and used in the operations research area. They start with the optimization of one single objective function. This kind of model is not applicable to our problem because there is no single organization that is optimizing the national containerized cargo importing and exporting. In our model, we assume each individual shipper optimize their own traffic only, without considering other shippers' decisions.

Survey-based research on the freight transportation choice decision has been a popular topic in the transportation and logistics literature. Murphy, et al. (1992) classified existing transportation choice research and presented their empirical work on major factors affecting people's behavior on international port selection decisions. Such analyses are useful in identifying important points for a port to improve its efficiency. However, they have limited use for an overall container transportation demand model, especially when the analysis should take into account the different port selection behavior for different cargoes, different trading partners, and the effects of multimodal transportation over a large transportation network.

Compared with the existing transportation demand models, our model estimates the container transportation service demand at ports by simulating the transportation process according to fundamental economic theory. We use the US waterborne international trade database. Our simulation process is directly based on the multimodal transportation network that combines truck, rail, and sea transportation. Also, we use the capital cost of containerized cargo as one part of the cost in the transportation process. Thus, different cargoes with different value will have incentive to select different routes. Furthermore, we use observed transportation freight rates for trucking, rail, and shipping in the modeling process, which could be used to analyze the effect of supply change of transportation facility on port container transportation service demand. Additionally, for new port construction, it is possible to add a new transportation route for the new port, then the demand for that new port can be calculated. Since this process is run within the

original transportation network, the substitution effect between the new port and existing ports will also be calculated.

II. D. 2. Data Requirements

Under the above stated assumptions, we limited our data needed to implement the simulation model to a minimal level. Nevertheless, application of the model still requires substantial data in three major categories: (1) intermodal transportation networks, (2) container cargo Origin and Destination (OD) data, and (3) economic data and freight rates.

II. D. 2. a. Intermodal transportation networks

The intermodal transportation networks include domestic (rail and highway) surface transportation and international waterways (shipping lines). The Oak-Ridge National Laboratory (ORNL) has established such a network, which can be used in our model. However, to shorten the simulation software development period, and to make our simulation model workable on a Personal Computer, we have to simplify all these networks. The simplified transportation network will use the National Interstate Highway System as the highway network, and the Class I multi-modal railway system as rail networks. We include only major container ports as the connection nodes between domestic transportation and shipping lines. At this point, we have selected a total of 18 ports: 5 on the West Coast, 4 on the Gulf Coast, and 9 along the East Coast (Table II-1). Selection of ports was based on annual throughput, with more detail for the US East Coast, the focus area for this research project.

II. D. 2. b. Container Origin and Destination data

Current data regarding containerized cargo imports and exports are from the US Maritime Administration, Department of Transportation (MARAD, DOT). This data set contains the value (in current dollar) and weight (KG) of annual imports and exports between a US port and foreign country for cargo categories detailed up to 5 digit SITC3 code and 6 digit HTSUSAS/Schedule B code (US Census, 2001). This data source has two problems: (1) It does not contain the number of containers and (2) It does not have origin for export and destination for import within the US. To apply this data in our simulation, we have to perform two transformation tasks:

- Transform the measure of each category from weight to number of TEUs.

It is well recognized that the commodity in a container could be homogeneous (only one kind of cargo) or heterogeneous (different kind of cargo). Moreover, even for the same kind of cargo, containers consolidated in different places may have different weight. Therefore, the conversion from commodity weight to number of TEUs is appropriate, given our need for TEU equivalent statistics for aggregated annual data.

Table II.1 Port Used in Demand Simulation Model and 1999 TEUs

Region and Ports	TEUs ^a
<i>East Coast</i>	
Boston	154,175
New York	2,828,878
Norfolk	1,306,537
Savannah	793,165
Charleston	148,995
Jacksonville	771,882
<i>Gulf Coast</i>	
Houston	1,001,170
New Orleans	268,630
Mobile	11,184
Tampa	6,905
<i>West Coast</i>	
Seattle- Tacoma	2,761,059
Portland	293,262
Oakland	1,663,756
Long Beach/Los Angeles	8,237,331

^a MARAD

Also, different cargo classification systems (HS, SIC, SITC, etc.) will have different cargo contents. Furthermore, even for one classification system, there will be a different average weight per TEU at different levels of commodity aggregation (2 digit, 4 digit, 6 digit, etc.). For the purpose of this research, we will start by using the average conversion from weight to TEU using the SIC 2-digit category. Research of average weight per TEU can be found from Hancock *et al* (2001).

- Transform the origin of export and destination of import to specific states.

Waterborne trade data (MARAD, 2000) and the US Census International Trade Database (US Census, 2001b) only provide data for custom districts. This does not necessarily coincide with the origin of exports or the destination of imports. This requires the allocation of exports and imports by States.

For export, the International Trade Administration (ITA) provides State Export to different country by industry categories (ITA 2001). This data can be used to allocate the total waterborne trade to each State.

For imports, there is no data equivalent to that available for exports. We will use a time series analysis to set up a relation of commodity import with economic and demographic attributes of each states. Then we will use an optimization process to estimate the import country by each commodity.

II. D. 2. c. *Economic data*

Economic data involved in this simulation model includes trucking, railway, and shipping freight rates. Since we are working on annual cargo transportation quantity, and the estimations are also made on an annual basis, we will use annual average of freight rates for all the three transportation facilities. For intermodal facilities, like inland container yards, we will use an average rate. Charges on container port (terminal changes) are subject to each individual port.

II. D. 3. **Implementation**

In deciding what methods to use to implement the simulation model, several criteria are used. These include: (1) the nature of the problem, (2) the data needed for our simulation, (3) the desired way for presenting the simulation results, and (4) the future possibility for extension to the University of Rhode Island, Department of Environmental and Natural Resource Economics, SimLab Decision Support System.

Our problem is to select the least-cost transportation route among all the feasible routes for certain containerized cargo, from cargo starting point to the destination. The nature of the problem requires the use of some kind of **transportation network routing algorithm**. An extensive literature exists on the efficient network routing algorithm in both transportation research (e.g., Southworth and Peterson, 2001, Wong et al, 2001) and computer networks research (e.g., Gavaille, 2000). This work will require the use of a transportation network which includes highway, railway, international shipping line, and connection nodes between railway and highway, and surface transportation and sea transportation. These data are available in ORNL inter-modal transportation networks (ORNL, 2001). These intermodal transportation network data have been used for 1997 Commodity Flow Survey (CFS97) for the simulation of different combinations of truck, rail, and water transportation.

The decision on how to apply this simulation model will depend on the availability of software packages that can meet the needs of our model requirement. If we can access available software (like the one ORNL used in CFS97), we can save considerable time in software development, and only need to spend time changing the calculation of link cost and re-arrange the result output. It is also tempting to use some higher level (Fourth Generation) programming languages³, like GAMS, MatLab, or Avenue for our simulation work, since it could save some software development effort by leaving some programming details to these high level packages. If we cannot find available software or high-level programming languages, then we have to program using lower level programming language, like C++ or Java, starting from the very beginning. To

³ Forth Generation Language (4GL) is the programming language within special purpose packages. The first generation is the machine code, the second is the assemble language, third the common purpose programming language (like Java, C, C++, FORTRAN, PASCAL, etc.). Programs write in SAS, SHAZAM, LIMDEP, GAMS, MatLab are 4GLs that are developed using common purpose programming language.

incorporate the simulation model into URI Simlab, the first two approaches need modification, while the last one can be specifically programmed according to the protocol used in URI Simlab.

Graphical data presentation is a major consideration in presenting the results of our simulation model. As Geographical Information System (GIS) has proven to be a very useful tool in the representation of geographical result, we will use GIS in the presentation of simulation results.

Appendix 1: Mathematic Model for container transportation service demand at port.

A.I. Introduction

Here we develop a basic model for the simulation of container transportation for US coastal container ports. A simplified depiction for the transportation process is illustrated in Figure II. A.1. Depicted here are choices of moving goods between East Asia (e.g. China), denoted “a”, and the US Mid West (MW) and the East Coast (EC). Shippers can use WC ports and the mini land bridge to reach the MW or the EC; or alternately shippers can use offload use the all water route for delivery to the EC and MW. The model described in the above text and presented more formally here attempts to capture key features of this problem. Of course, the transportation process is very complex and any model is an abstraction. A good model will mimic reality reasonably well, and hence the ultimate test of the model will come in its application, and from refinements based on experience gleaned from early applications and acquisition of better data.



Figure II.A.1. Simplified depiction of transportation route selection between East Asia (“a”) the US Mid-West (“m”) and East Coast port (“n”)

A.II. The Model

Assume there are Q_{ami} containers (in TEU) of cargo category i ($i \in [1, I]$) to be imported from world region a (a continent) to one destination m in the US (a state) (*Export is the reverse process of imports*). The ship cost is α dollars per mile per TEU. There are N coastal ports to choose from in the US, and the ocean distance of region a to the n^{th} ($n \in [1, N]$) container port is l_{an} . The port charge at the n^{th} port is p_n per container.

The domestic transportation cost from the n^{th} port to the destination m is the sum of the costs spent for each transportation mode. Assume for mode j ($j \in [\text{truck, rail, inland waterway}]$) the unit cost is β_{nmj} per container per mile, with inland transportation distance l_{nmj} . The sea transportation speed is S_s miles per hour, domestic transportation speed is S_{ij} miles per hour, and the port dwelling time for n^{th} port is H_n days. Also, the value of the cargo i in a container is V_i , and the daily unit cost of capital is ρ (i.e., the interest cost on the investment in cargo). The total number of cargo categories is I .

- Transportation Costs

Transportation cost is the sum of the fees paid to the transportation facility providers for the use of the facilities (truck, rail, port, and container vessel). For some routes, railway may not be used, so rail cost may not appear.

For one container from an origin in a particular world region a to one particular place (state) m in the US, the total transportation cost (C_1) using n^{th} port is:

$$C_1(n) = \alpha * l_{an} + p_n + \sum_j \beta_{nmj} * l_{nmj} \quad (1)$$

- Time Cost

The time spent on a sea leg is $l_{an}/S_s 24$ days, in port is H_n days, and in domestic travel is $\sum_j \frac{l_{nmj}}{24S_j}$ days. Thus, the total number of days spent in transit is:

$$D_n = l_{an}/S_s 24 + H_n + \sum_j \frac{l_{nmj}}{24S_j} \quad (2)$$

For cargo i , the opportunity cost of time for the cargo value:

$$C_2(n) = V_i [(1+\rho)^{D_n} - 1] \quad (3)$$

Other costs that can be expressed as a function of time, like cargo depreciation, refrigerated (“refer”) box rental, can also be included.

- Total cost in the transportation process

The total cost in transit by using n^{th} port for cargo i is the sum of the costs from (1) and (3) above:

$$TC_i(n) = \alpha * l_{an} + p_n + \sum_j \beta_{nmj} * l_{nmj} + V_i [(1+\rho)^{D_n} - 1] \quad (4)$$

Assuming the shipper selects the least-cost route for containerized good i , the selected container port is the one that minimizes $TC_i(n)$. i.e.,

$$\min_n \{TC_i(n)\} \quad (5)$$

Assume through the selection of the least cost route, there are Q_{ami}^n containers of cargo i from a to m that will use port n . Then, the annual demand of port n is:

$$Q(n) = \sum_a \sum_m \sum_i Q_{ami}^n \quad (6)$$

As can be seen from the above discussion and equations, changes in such factors as sources, vessel speed, costs of different facilities, and changes in markets, or interruption of services at ports rails, roads, or other changes all will affect the demand for port container transportation services. Once developed, the model can be used to gain insight into how the demand for port container transportation services will be affected by changes in these (and other) factors.

III. PORT INVESTMENT APPRAISAL AND RISK ANALYSIS

III. A. INTRODUCTION

This chapter presents the concepts, methods, data, and assumptions for that part of our framework dealing with financial feasibility and risk analyses for port (really, terminal) development. First, we discuss key concepts underlying investment appraisal for a terminal operator, emphasizing standard discounted cash flow analysis and net present value for an operator (NPV^o) (e.g. Levy and Sarnat, 1990). Next, we describe important sources of risk facing port operators. We then go on to illustrate the estimation of NPV^o, using generalized data for a hypothetical port at Quonset Point, RI as a case study.

Our main purpose in this chapter is to present key concepts and methods and to illustrate the importance of directly addressing the many uncertainties involved in assessing port investment. To this end, we carry out several sensitivity analyses, as well as more formal risk analysis using Monte Carlo methods and discrete, dynamic event analysis, as explained later in this chapter. The many sources of uncertainty associated with port proposals -- especially at an early point in the consideration of port development -- make it more appropriate to ask: “What is the expected value of NPV^o of the proposed development?” or “What is the *chance* that a proposed port will be economically viable?” rather than “Will such a port be profitable?” Our illustrative case study underscores the importance of specifically accounting for sources of risk and uncertainty and identifying issues needing further investigation.

We stress that our goal is simply to illustrate a methodology—*not* to assess the feasibility of a port at Quonset point. Existing studies¹ of a possible port at Quonset Point represent *concepts* of a possible port -- not firm, specific, and detailed plans. As a result, we do not have sufficient confidence in these studies to rely upon them to carry out a rigorous feasibility assessment, nor have we attempted to develop an original, in- depth engineering-economic study of a container facility at Quonset Point, something which is beyond the scope of our Year One work. Instead, for this exercise, we glean and adapt information from several sources and use generalized information simply to illustrate useful concepts and the investment feasibility methodology.

A note on terminology is in order. The terms “port” and “terminal” often are used interchangeably. However, we can think of a port as being comprised of a quasi-government entity, such as a Port Authority, and one or more container terminals. This is a common form of port organization in the US and, indeed, throughout much of the world. The “Port Authority”

¹ Two studies have been done of a possible container port at Quonset Point, one for an earlier (and withdrawn) proposal by Quonset Point Partners (1999) and a second by RK Johns & Assoc. (2000). A critique of the RKJA report is given in Vickerman (2001), who carried out an analysis at the request of the Town of North Kingstown; a response to this critique can be found in RI Economic Development Corporation (2001).

promotes the port, oversees and coordinates its development and operation, allocates terminal space, facilitates development of intermodal facilities, and carries out other functions, such as ensuring environmental compliance. Terminals offload containers from vessels and move them to container box storage areas where they are subsequently picked up by trucks for delivery, usually within 200-300 miles. For delivery to more distant markets, boxes usually are loaded onto double-stacked trains for shipment. Exports of containerized goods, of course, operate the opposite way, and container vessels calling at a terminal will deliver and pick up at least several hundred containers per visit.

We assume that the terminal is operated by a private entity with out-of-state owners. This assumption will become important in Chapter V when we present that part of the framework dealing with the size and distribution of the benefits and costs from port development.

III. B. CONCEPTS

Worthwhile new business ventures must earn shareholders a rate of return, after taxes, which is at least as high as they could earn in the next-best use of their funds. The standard criterion for assessing the feasibility of an investment is Net Present Value (NPV), which includes all incremental cash flows paid for or received by the operator. Applied to our container port problem, the formula (ignoring taxes) for the NPV^0 for a terminal operator at time t_0 is:

$$NPV^0 = \sum_{t=t_0}^T \frac{(R_t^o - F_t^o - C_t^o - I_t^o - M_t^o - MIT_t^o)}{(1+r)^{t-t_0}}$$

Where:

NPV^0 = Net present value to a container terminal operator

I_t = the operator's investment outlay in year t

R_t = the revenue received in year t

F_t = fees paid by the operator in time t

C_t = operating costs in year t

M_t = maintenance costs in time t

MIT_t = mitigation costs in time t

R = the discount rate (weighted average cost of financing)

t_0, T = respectively, the first and last periods considered in the analysis

Worthwhile investments must have a positive NPV^0 , and the NPV^0 is in principle the maximum a prospective company would bid for the right to develop and operate the terminal.² A negative NPV^0 reveals that the project would require a subsidy to be

² In fact, in Korea and elsewhere in Asia, companies do bid for the right to operate a terminal, so the concept is more than a theoretical proposition.

feasible. In the port context, “I” will include all port and site development costs, including equipment (superstructure) and other indirect costs (e.g., permitting, special studies) that are incremental cash flows to the private terminal operator.

From the above formula, it is apparent that the NPV⁰ depends on projected values for many factors: revenues, investment costs, productivity, the timing of cash flows, the discount rate, etc. *Our later sensitivity analyses show how the magnitude of NPV⁰ depends critically on key assumptions and judgments made by researchers and prospective investors about the specific values used for all of variables indicated.* As we will see, in particular, the estimate of the start up number of containers through a port turns out to be very important for the cases we consider in our hypothetical, illustrative case study for Quonset Point.

For most private sector investments, income taxes have an important effect on feasibility. Taxes, however, raise specialized issues that are beyond the scope of the present effort and are not considered further in this report. We note, however, that in present value terms, income taxes on port operations are unlikely to be an important issue in most cases. This is due to the long period required for port development, the additional time until profits are earned, and the ability to carry losses forward to charge against future profits. All of these considerations suggest that income taxes on a port operation are unlikely to be important. (However, fees paid by a successful terminal operator to a state authority potentially can be considerable, as we show in Chapter V.) Should income taxes prove to be important for the case study, this issue can be revisited in the next phase of our work.

III. C. RISK AND UNCERTAINTY

Rarely, if ever, are investment decisions in any business area certain, and this is particularly true for container ports due to long lead times, competition, and other factors. Instead, many different outcomes for NPV⁰ can be projected for a port, depending upon the estimates or judgments one makes about important variables (start up volume, growth, costs, etc.) to be used in the analysis.

The alternative estimates of NPV⁰ arrived at using different assumptions reflects the degree of uncertainty involved with a prospective investment. The dispersion of these outcomes (i.e., their variance) indicates the degree of risk faced by investors, with more dispersion reflecting greater risk. Of particular interest is the percent of time the NPV⁰ is negative. How potential investors will react to and use this information in decision making depends upon their attitude toward risk (see, e.g., Levy and Sarnat, 1990), which will vary among individuals and groups.

Below, we describe different sources of uncertainty in general and particular risks faced in planning for container port development. We follow convention and use the terms

“risk” and “uncertainty” interchangeably. We also illustrate in our case study how risk and uncertainty can be analyzed using several approaches.

III C. 1. Business and Financial Risks

Business risks arise from the inherent nature of the activity and the overall economic conditions in which a business operates. Demand for the port may be lower (or conceivably, higher) than anticipated; or prices or costs may be higher (or possibly lower) than planned. Environmental regulations and mitigation also pose major risks for port operators. Any – or all – of these factors can and likely will turn out to be different than originally anticipated. Collectively, these risks are referred to as business risks.

Of course, businesses can and do take measures to reduce uncertainty. They do this by spreading risks, seeking long-term contracts, using futures markets for commodities and foreign currency in futures exchange markets, diversifying activities, and purchasing insurance. Despite these and other risk-reducing measures, however, risk and uncertainty are a fact of life, and furthermore, not all risk can be insured against (e.g., national or international recessions or conflicts).

The high fixed costs of port operations potentially raise special challenges. This is particularly true for operations that are highly leveraged, i.e., financed heavily by debt, which require that fixed loan repayments be made regardless of business conditions (“financial risk”).

Ex-ante judgments rely on expert opinion, assumptions, and scenarios, but *ex-post* results often differ considerably from *ex-ante* assumptions. Of particular importance to port planners are: (1) the start-up volume of containers, (2) productivity of the operation, (3), revenue items (i.e., revenue per TEU), (4) environmental costs, (5) period of the project, (6) wages and labor stability, (7) the discount rate, (8) land space required and the price of land (opportunity cost), and (9) infrastructure items (rail, truck, barge). These items directly affect the decision of whether to develop a port or not, and, therefore, the utmost care should be taken in undertaking a feasibility study. Our later case study illustrates the importance of accounting for many of these different sources of uncertainty.

Given the many sources of uncertainty, even the most carefully developed proposal will face considerable risk, and it is important to carry out sensitivity and other, more robust analyses of risk and uncertainty in estimating NPV⁰. This type of analysis gives an idea of the potential range of possible outcomes. It also helps to identify factors that seem most important in understanding the source of uncertainty and that, therefore, may warrant action or further study before a major investment is made.

III. C. 2. Other Risks

Risks for investing in a new container port and/or expanding an existing port come from many more different sources than traditional business and financial risks due to involvement of many different stakeholder interests in port investment. We mention these below.

A decade ago, Frankel (1989) listed types of risks in project appraisal as: (1) Physical, (2) Financial and (3) Economic. While conducting interviews with major North American container ports, we found that contemporary port planners are confronted with new issues and changing aspects of traditional risk items. Particularly of interest to the planners are (1) *environmental issues*, (2) *demand and port competition*, (3) *port financing*, (4) *labor*, (5) *yard operational efficiency*, and (6) *intermodal connections*. We describe each of these below.

Environmental issues (real and perceived) have become a major barrier to developing a container terminal. For instance, the Port of New York and New Jersey (PNYNJ) has been stymied in its plan to dredge channels by environmental restrictions on disposal and requirements for dredging windows and therefore is unable to accommodate super post-Panamax vessels. A similar situation is also found in the Charleston, SC, particularly in the Daniel Island port development plan, where the original development plan was rejected due to environmental and other concerns.

Specific environmental issues vary between ports, but often involve concerns about loss of valuable natural services and potential risks to the public's well being. A generic listing of *potential* environmental issues would include: (1) dredging and dredge disposal, (2) loss of wetlands, shoreline, and bay bottom due to fill and construction, (3) air emissions from trucks and to a lesser extent, rail traffic and vessels, (4) water pollution from storm water runoff, (5) offsite, peak-use road congestion, (6) higher maintenance costs due to accelerated wear and tear on roads, (7) loss of open space amenities in nearby communities, (8) light and noise externalities near ports and, in the case of noise, along routes heavily traveled by trucks, (9) traffic delays at offsite rail crossing used by trains carrying containers (e.g., MARAD 1994a and 1994b, Colorni *et al* 1999, Federal Register 1997, Grigalunas *et al* 2000, WADOT 1999), (10) physical interference with seasonal fish spawning runs, and (11) potential conflicts with commercial fishing and recreational uses of area waters.

First and foremost, an initial assessment should ascertain whether a potential environmental issue will, in fact, be a real issue (i.e., external cost) at a particular facility. For example, use of extensive bright lights and noise at facilities may be controlled by design measures and may not need to be a serious issue in a particular case.

Analysis of environmental effects can contribute to port development decisions in several ways (e.g., Grigalunas, et al., 2001). First, monetary estimates of environmental costs put all benefits and costs on the same footing and by that, place environmental costs in

perspective. Unless such quantification is attempted, perceptions of potential environmental costs may be grossly understated--or overstated--with little or no objective data to assess the relative significance of these concerns. Further, quantifying costs can highlight and direct scarce resources to the most important concerns and away from relatively minor issues. Quantifying potential external costs may also contribute to selection of a preferred site for marine disposal of dredged sediments, choice of the type and scale of actions to mitigate potential adverse effects of port development, for example, loss of wetlands due to construction (Mazzotta *et al*, 1994), or the efficacy of using of dredging windows to avoid some marine environmental costs influenced by seasonal factors, e.g., spawning period. All of these may affect an operator's cost and hence the scale, design and feasibility of an operation. Potential environmental issues are examined in some detail in Chapter IV.

Demand issues are still a major concern to the decision makers, particularly as *port competition* gets fierce. The following recent remarks about the East Coast port competition and risks are instructive (Prince, 1999):

The plot surrounding the decision by Maersk Line and Sea-Land Service on where to locate their proposed North Atlantic container hub is no less complicated.... Since that announcement, industry pundits have been hard at work handicapping each candidate's advantages and disadvantages.... Maersk and Sea-Land are playing the ports against each other. This is certainly a masterful negotiating strategy.

New entrants to the container port business, in order to get a market share, will take some promotional market measure. This will affect the profitability of existing ports, and as a result, the new entrant will be subject to the retaliation from existing ports. Risk exists in whether the proposed port can survive the resulting, fierce market competition.

Some idea of recent inter-port competition in the Northeast is given by the PNYNJ's plan to establish a Port Inland Distribution Network (Moffatt & Nichols, 2001). This would establish inland distribution centers at key "trade clusters" in the Northeast, which would be fed by train or vessel (barge) corridors from the PNYNJ. These centers would presumably compete with other ports vying to service these market areas.

Thus, fierce competition exists among ports and between ports and shipping lines. But this competition is not the perfect competition taught in textbooks, where operators carry out their activity with no concern for responses of others in the market. Rather, there are important interdependencies and elements of strategic interaction common to monopolistic competition and oligopolies³.

³ Interdependencies among ports and shipping lines and the potential for strategic behavior among market participants opens the door for interesting applications of game theory by businesses or government.

Port *financing* is another area of concern to port decision-makers. Modern container terminals require huge capital investments, easily in the hundreds of millions of dollars, and in some cases billions of dollars. Port investment often has a longer pay-back period and greater-than-average risks and uncertainties. Accordingly, port authorities and port developers have difficulties in finding financial sources.

The principle sources used to finance port development are (1) public financing, (2) private financing, or (3) partnership between public and private entities. Typically, the public sector has taken the lead for major parts of port investment, and this is particularly true in the developing world. Private financing is carried out commonly through issuing bonds by port authorities, and in some cases commercial bank loans are explored. In recent years, major shipping lines become port investors as a part of their global transport network strategy. Sealand-Maersk line, OOCL line and P&O line's container terminals on a global scale are good examples. On the other hand, the Port of Seattle has worked with railroads to share the high cost of rail access to terminals. Washington State ports also have the unique opportunity to assess property taxes on residents of the county in which they are located.

Partnerships between public and private sectors and/or between the central government and local government as well as private sectors are an increasingly important approach for investment in different parts of the world. This form is more common in the developed world, often forming a consortium. Korea introduced this approach to its new Pusan Kwaduk Container Terminal and has been encouraging more partnerships in port investment.⁴ In sum, port financing issues are major concerns to port developers and may be an obstacle to implementation of their plan.

Labor has been a persistent concern to port managers and is likely to be so in the future. It is not only developing countries that suffer from labor issues; developed countries do as well. Even though privatization and commercial efficiency are emphasized in developed economies, port labor tends to be unionized soon after a port begins its operation with non-unionized staffs. The Port of Charleston in the U.S. was found to fall in this category, and there exist many other similar cases in the world. During our interviews, some port planners insisted that the most important factor to the success of a new container terminal is to develop a non-unionized facility. To lessen this labor issue, some ports attempt to develop highly automated terminals, even thinking about virtually unmanned terminal. Regardless of the preference of port managers, there is always human involvement in port operations, which renders the labor issue a constant concern to managers and planners.

⁴ A new container terminal is to be developed from 1995 to 2011 to provide 30 berths with an annual handling capacity of 8.1 million TEUs at the cost of about seven billion dollars. The private sector is anticipated to provide 40% of the total investment.

Another area of traditional concern to port planners is the *efficiency of yard operation*. For instance, there is growing concern at the Port of Charleston, S.C., as to how to increase the port productivity before physical expansion by developing a new site, like the proposed Daniel Island project. Before developing the new site, the port is exploring ways to increase its productivity such as longer working hours, reducing gate-passing time, stacking boxes higher in the container yard, and more efficient yard management. Indeed, improving efficiency in the face of congestion is a national issue in the US (e.g., Mongelluzzo, 2001). Similarly, container terminals in Pusan, Korea strive to increase their yard operational productivity to meet recent (1999-2000), sharp increases in container cargoes. Pusan terminal managers argue that they can increase yard operational productivity by even 60% through optimizing yard operational efficiency.

Port yard operation systems vary between terminals. The differences result from: (1) type of cranes used in quay and yard, (2) layout of yard space between import, export, transshipment, and empty boxes, (3) free storage period for boxes, (4) connection with inland intermodal system either by train, truck or barge, (5) labor provisional system, (6) stacking method of boxes (for instance, between ground operation⁵ and wheeled operation⁶), (7) storage for chassis, and (8) gate passing system. The yard operation system managers in the ports that we interviewed in North America and Korea seemed to have always something to be improved.

Finally, *intermodal connection* is an issue of critical importance for port planners, particularly for ports transporting goods long distances and facing restrictions on trucking due to congestion. In such cases, intermodal transportation plays a key role in determining the terminals' future. As noted, the PNYNJ has proposed development of a new rail and barge distribution system throughout the northeast, in order to avoid severe highways congestion. The Mini-Land Bridge (MLB) concept, involving the delivery of containers from West Coast ports to the Midwest and East Coast has been successfully developed in North America. Similar development has been undertaken between countries in Europe and Asia. As a result of the need to move large volumes of containers long distance, and environmental constraints and economic factors, modern hub ports have a tendency to install rail access on-site of its terminal. Facilitating on-dock rail system is a capital-intensive decision, however, and makes terminals dependant upon rail companies' destinies. Further, major rail companies in North America, have had merger problems between them, therefore making the terminals exposed to risks and uncertainties from this source.⁷ (Journal of Commerce, 2000)

⁵ Stacking boxes not on chassis, but box-on-box.

⁶ Stacking boxes on chassis.

⁷ Three years ago, CONRAIL was merged by Norfolk South (NS) and CSX (Sealand group) and another merger is ongoing between Burlington Northern Santa Fe Corp. (BNSF) and Canadian National Railway Co. (CN). Such mergers have come under intense scrutiny and approval is not assured with attendant risk to all parties.

In summary, all of the above factors indicate important uncertainties and risks facing prospective port developers. Therefore, great emphasis should be given to assessing the significance and nature of the risks and also how to minimize them. The risk assessment methodology presented in the next section serves to illustrate the importance of some of these different sources of risk.

III. D. ILLUSTRATIVE APPLICATION OF INVESTMENT FEASIBILITY AND RISK FRAMEWORK TO HYPOTHETICAL CONTAINER TERMINAL AT QUONSET POINT, RHODE ISLAND

III. D. 1. Scope and Methodology

This section presents the results of several computer simulation models of development of a hypothetical container terminal. Simulation models are one of the dominant techniques in the operations research field, and their usage is pervasive. Their popularity stems from the power of such models (1) in representing a system of concern and in a way that can contribute to problem solving, and (2) from the reduced cost of using increasingly powerful computers due to technology development.

The maritime field has not been an exception in this trend. Of the many applications of simulation models in the maritime field, the major studies can be classified into three categories according to the purpose of the study: short-term operational analysis, long-term investment appraisal, and shipping market analysis. Examples of operational analyses are those by UNCTAD (1969), Collier and Litherland (1979), Wadhwa (1980), Kondratowicz (1992), and Standridge and Tsai (1992). Investment appraisal using simulation models has been done by Frankel *et al.*, (1973), Bressman *et al.* (1978), Fuller *et al.* (1983), Sheikh *et al.* (1987), Park and Noh (1987) and Y.-T. Chang (1992). Illustrations of shipping market analysis include Buxton and Akgul (1989), and Lin and Chen (1992).

Three types of computer simulations are used in this section to illustrate the assessment of investment feasibility and risks for a prospective container terminal operator:

- Sensitivity (“What if?”) analyses
- Monte Carlo simulation model, and
- A discrete-event, dynamic stochastic simulation model (the “event model”).

The first two analyze the financial soundness (in terms of NPV⁰) of the project to a private terminal operator. The third method – the event model -- examines the operational aspects of the port. We describe the first two simulations next in some detail, emphasizing throughout the preliminary and (at this stage) simplified nature of the

analysis. Then, we provide some important qualifications and caveats. Details of the event model are given in an appendix to this chapter.

III. D. 2. Sensitivity Analyses

III.D.2.a. Cases Considered

To illustrate the port investment and risk analysis framework described above, we use generalized information for a port under discussion for Quonset Point, on Narragansett Bay, Rhode Island. The sensitivity of the NPV^o results to changes in assumptions are estimated by varying three factors separately: (1) startup container moves, (2) annual growth rate in moves, and (3) gantry crane productivity (Table III-1). The table also shows other key assumptions used. The ranges employed for year 1 moves and annual growth rates are intended to bracket conceivable possibilities purely for the illustrative purposes for our sensitivity analyses.

Table III-1. Key Sensitivity Analysis Assumptions and Parameter Values Used for NPV^o for Hypothetical Quonset Point Container Port

• Moves in Year 1 (thousands):	200	300	400
• Annual Growth Rate:	4 %	6%	8%
• Productivity (Gantry Cranes Moves/Hour)	30	40	50
• Fee per move:	\$200		
• Fee paid to State in lieu of lease:	\$75/move up to 500,000 moves/year		
• Fee paid to town:	.004 of total terminal revenues		
• Discount Rate:	7 %		

Summary information given in Table III-2 shows key development information, and Figure III-1 shows the assumed time profile of site and terminal development and operations for a 24-year period. This information is critical for carrying out financial analyses. These engineering data are adapted from RK Johns & Assoc. (2000) (RKJA). A similar time profile is given in an earlier proposal by Quonset Point Partners.

The terminal facilities envisioned in the RKJA report are a highly automated, state-of-the-art operation, modeled on the best container terminals in Europe⁸. The planned, sustained 50-container gantry moves per hour is far superior to — perhaps more than double the productivity — achieved at other US facilities, to our knowledge.

⁸ The DELTA terminal outside of Vancouver, British Columbia, visited by the study team during our research, might also be viewed as a model of a state-of-the-art container terminal. The facility achieves about 25 – 30 moves per hour.

The highly automated nature of the terminal operation is underscored by the small work force at the terminal envisioned by RKJA. Initial employment on the dock would range from 66 at the outset of operations to 315 in year 20, and depends upon the annual container throughput. Yard workers and gate employees would begin at 50 and increase to 125 at the 20th year of operation. Administrative employment would start at 50 and reach 150 in the 20th year of operation.

To examine what the consequences for NPV^o would be if different crane productivity standards are achieved, we use alternative productivity estimates ranging from 30 – 50 moves per hour. Further, note that in our NPV^o model, the number of yard workers used is a function of the productivity of the gantry cranes. Hence, if actual productivity is less than the planned 50 moves/hour, additional labor must be hired to move the number of containers assumed to pass through the port in a given year.

Specifically, we calculate the number of yard workers, N, as:

$$N = \frac{L}{C \cdot H} n \cdot 1.5$$

Where:

N: Number of yard workers

L: Annual total lifts

C: Crane efficiency (lifts/hour)

H: Annual working hours (use 2288 hours)

n: number of workers per gang (20)

1.5: Constant reflecting shift breaks, lunch, and overtime

We assume workers are fully employed (work 2288 hours a year), and their average hourly wage (w) is \$48. Therefore, the total labor cost for yard workers is: N*H*w, where these terms are defined above.

Additional engineering information is needed for our case study illustrative application. RKJA present four conceptualizations of a potential port at Quonset Point. All would be carried out in two Phases, eventually resulting in a terminal with 4,000 feet of berthing space, suitable for accommodating four large container ships. All development alternatives involve filling in of some Bay lands, ranging from 68 acres to 114 acres. Dredging of the approach channel and of a turnaround basin to at least 45 feet also would be required under all alternatives, and would result in 2.4 to 7 million cubic yards of material, net of use as fill to create port land. The open ocean disposal required ranges from negligible for two options to 3.0 million cubic yards for the other two options, depending upon how much of the dredged material is used for construction and beneficial uses (RKJA, p.5-8).

Investment costs given in RKJA include site and terminal development costs. Site development includes environmental mitigation, containment structure, navigational aids, and other site improvement costs. Terminal development costs include construction of the wharf. The total of these (including dredging) range from \$267 million to \$354 million or from \$333 million to \$525 million, depending upon (1) which port alternative is being considered and (2) whether the Federal government is assumed to pay a large portion of dredging costs.

Note that *who* pays for dredging and other costs is important for assessing the feasibility of the investment for the operator (i.e., it affects NPV⁰) the operator, as well as for state residents. At the national level, who pays does not matter: a cost is cost, whoever pays. *We assume throughout this Chapter that the terminal operator does **not** pay any separate cost for dredging, although such costs may be included in the \$75/box fee (Table III-2) paid to the state.*

III. D. 2.b. Results for Sensitivity Analyses

Selected model results from the private operator's perspective are summarized in the following tables. First, we consider interactions between (1) the number of initial moves, (2) the annual growth rate in moves, and (3) the sustained productivity level, measured as moves/crane/hour. Other variables used are held constant at the levels indicated in Tables III-1 and III-2 and Figure III-1.

Figure III-1: Timeline of Major Activities at Quonset Point (RKJA, 2000)

	Construction Period				Operation Period																			
Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Revenue flow																								
Dredging, landfill and disposal																								
Site Development																								
Terminal development																								
Phase 1																								
Phase 2																								
Purchase Equipment																								
Operational expenses																								

Table III-2. Information and Assumptions for Feasibility Analysis

Terminal Area	About 270 acres in total
Container Revenue	200-400 thousand moves in the first year of operation, then increase at about 4% - 8% per year. The initial per move charge is \$200.
Rent to State	A payment of \$75/move is guaranteed to state for throughput at 50 thousand moves in the first year up to 500 thousand moves per year.
Equipment	Includes Gantry cranes, Quay Conveyors, Rail Mounted Gantries, Yard/Yard Conveyors, Truck load/unload equipment, etc. The equipment numbers vary over time, with purchases in year 1 (\$81.5 million), year 6 (\$36.5 million), and year 12 (\$40.5 million).
Labor	Cranes efficiency: 30 – 50 lifts/hour. 20 workers per gang
	Number of dockworkers depends on the annual expected moves, and crane efficiency, as described above in text. 50 indirect labors (yard employee and gate clerks) in the first 5 years, 80 in the next 6 years, then 125 in the remaining years, with wage rate \$48 per hour. Administrative staff is 50 in the first 5 years, 75 in the next 4 years, 100 in the following 3 year, then increase to 150. Annual salary \$75,000.
Overhead Cost	Including utility, insurance & permit (\$3 million per year), and administrative expenses (1/4 of the administrative staff salary).
Maintenance & Operations	This includes annual equipment maintenance and power (initial \$7 million, with \$3 million additional cost for every subsequent purchase), infrastructure maintenance cost (assumed to be 5% of the site development cost).
Inflation rate	3%
Discount rate	7%

The results in Table III-3 can be summarized as follow:

- The worst case is a negative NPV^o of \$406 million; the best case a positive NPV^o of almost \$601 million
- *The start-up number of moves and the anticipated growth rate are critical for achieving a positive NPV^o.* The model results show a negative NPV^o when the number of startup moves is 200,000 per year, even with the highest annual growth rate considered, 8 %, and achievement of the goal of 50 moves per crane per hour.

- On the other hand, the operation is very profitable, *if* the initial moves are high, a high growth rate (6% - 8 %) can be attained, and a crane productivity of 40 to 50 moves/hour can be maintained.
- *Achieving and maintaining a high level of productivity is important.* Lower crane productivity leads to higher labor costs (to achieve a given throughput) and puts pressure on profitability.

Table III-3. Example Sensitivity Analysis Results for Terminal Operator Profitability (NPV^o)

Crane Efficiency	Start Moves (000)	Annual Growth Rate		
Lifts/ Hour		4%	6%	8%
30	200	(\$406)	(\$315.74)	(\$201.87)
	300	(\$187.65)	(\$52.51)	\$118.29
	400	\$30.53	\$210.72	\$438.45
40	200	(\$371.24)	(\$274.00)	(\$151.11)
	300	(\$135.76)	\$10.09	\$194.42
	400	\$99.71	\$294.18	\$539.96
50	200	(\$350.48)	(\$248.96)	(\$120.66)
	300	(\$104.63)	\$47.65	\$240.66
	400	\$141.22	\$344.26	\$600.87

III.D. 3. Monte Carlo Simulation Model for NPV^o

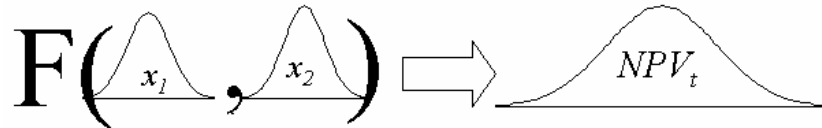
III.D.3.a. Introduction

Monte Carlo simulation is defined as a simulation model to be a scheme employing random numbers, that is, univariate – U (0,1) -- random variates, which is used for solving certain stochastic or deterministic problems where the passage of time plays no substantive role (Law and Kelton 1991). If there is more than one uncertain variables, than a multi-variate Monte Carlo analysis is appropriate for the risk analysis to examine the combined effect of these uncertain variables. When there is uncertainty concerning a cost-benefit analysis and financial analysis, Monte Carlo analysis is often used. This method simulates the possible range of outcome by specifying random distributions for key, selected, uncertain parameters.

The first step of Monte Carlo simulation is to establish the relationship between the objective values (for instance, NPV to a private developer or operator) to all variables (existing information and assumptions), i.e., to establish the function $F(\bullet)$ of objective value (NPV) in terms of all the variables $NPV = F(X)$ assuming nothing is uncertain, then:

$$NPV = F(X)$$

The second step is to select key variable (s) which are uncertain and important, and specify the distribution for each variable. The last step is to run the simulation. When some (or all) of the variables are not certain, then each time we need to use one possible value from the distribution of the variable to calculate the NPV_t . If there are two random variables (assume x_1 and x_2 , with distribution f_1, f_2), after many times repeated calculation, then the resulted distribution of NPV would be f , as illustrated below:



This Monte Carlo result provides the distributions of possible outcomes of NPV to a private developer or operator, given the distributions of the input variables. It indicates (1) the effect of uncertainties of input variables on the outcome, (2) the risk of investment in this project. Haralambides (1991) well exemplifies this method.

III.D.3.b. Application

Cases considered. We simulated port development using: Startup container volume, the growth rate, costs, and the planned productivity of a port. We use a probability distribution to characterize the uncertain variables rather than using a few cases and, further, a probability is attached to different ranges of the variable of interest. For each variable, we ran 10,000 cases. Important issues are: Which distribution to use? And what should be the key characteristics of the parameters of the distribution (mean and standard deviation)?

We use a normal distribution in all cases but truncate the distribution, as explained below and illustrated in Figure III-2. For the startup boxes moved, for example, we use a range of 200,000 – 400,000. The lower range reflects a judgment that a port would not proceed without a substantial commitment by a shipping line. The upper range is used simply to explore the consequences of using a “most optimistic” case.

Our container moves growth rate assumption includes a maximum of 8 %, an “optimistic rate” (the projected rate for the dominant and highly successful PNYNJ (Ellis, 2001)), while the lower rate of 4 % reflects a possible economic slowdown. Our productivity per crane range used in the model is meant to explore the consequences for NPV⁰, if a rate of 50 moves/box/year cannot be attained or sustained. The following table and figures summarize assumptions used for the Monte Carlo analyses.

Table III-4: Parameters Of Input Distributions (Normal Distribution) For The Monte Carlo Simulation Model

Parameters	Range	Mean	Standard Deviation
Initial Container Moves (000)	200-400	200	133.3
Growth Rate in Moves	4 % - 8 %	6 %	2%
Cost	-10% to +10% of base case	0%	4%
Productivity (Moves/hour/crane)	40 – 50	40	8

III.D.3.c. Results for Monte Carlo Simulations

Results for the Monte Carlo simulations are given in Table III-6 and are summarized in Figure III-3 for the *combination* case, which includes the influence of *all* four of the uncertain variables considered. Given the assumptions used, the expected value (i.e., the average) outcome is negative \$14 million – essentially a breakeven proposition, given the many strong assumptions necessarily employed in this analysis.

Note that the risk of a loss (a negative NPV⁰) for the variables used in Monte Carlo analysis ranges from 23 % for variations in costs to 61 % for variations in initial moves. Thus, a key result is that uncertainty with respect to *initial throughput of containers* through the port is the major source of risk in NPV⁰ for the private terminal operator.

Figure III. 2. Assumptions Used in Monte Carlo Analysis

Assumption: Cost

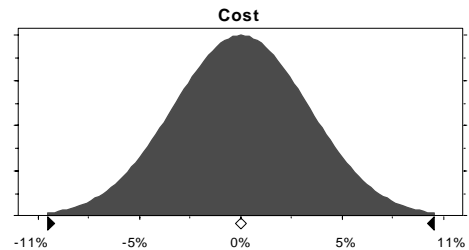
Normal distribution with parameters:

Mean 0%

Standard Dev. 4%

Selected range is from -10% to +10%

Mean value in simulation was 0%



Assumption: Initial Moves

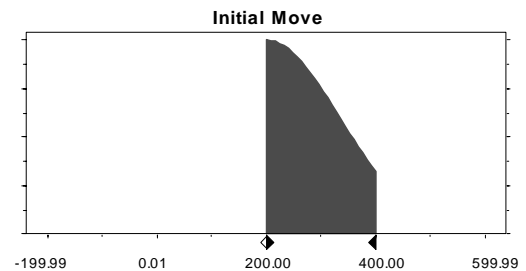
Normal distribution with parameters:

Mean 200

Standard Dev. 133.33

Selected range: 200,000 to 400,000

Mean value in simulation was 282,700



Assumption: Growth Rate

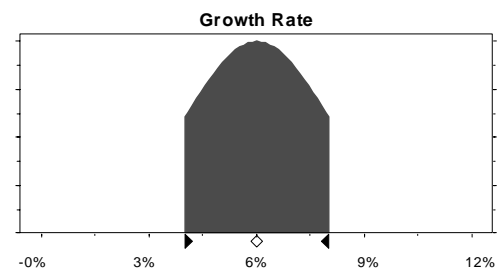
Normal distribution with parameters:

Mean 6%

Standard Dev. 2%

Selected range is from 4% to 8%

Mean value in simulation was 6%



Assumption: Crane efficiency

Normal distribution with parameters:

Mean 45

Standard Dev. 4

Selected range is from 40 to 50

Mean value in simulation was 45

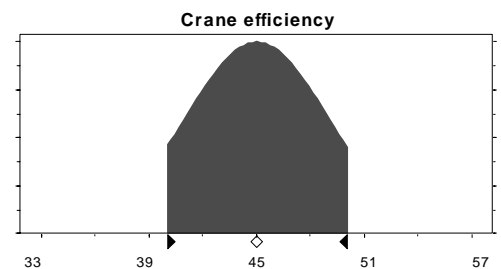


Table III-5. Monte Carlo Analysis: Summary Results

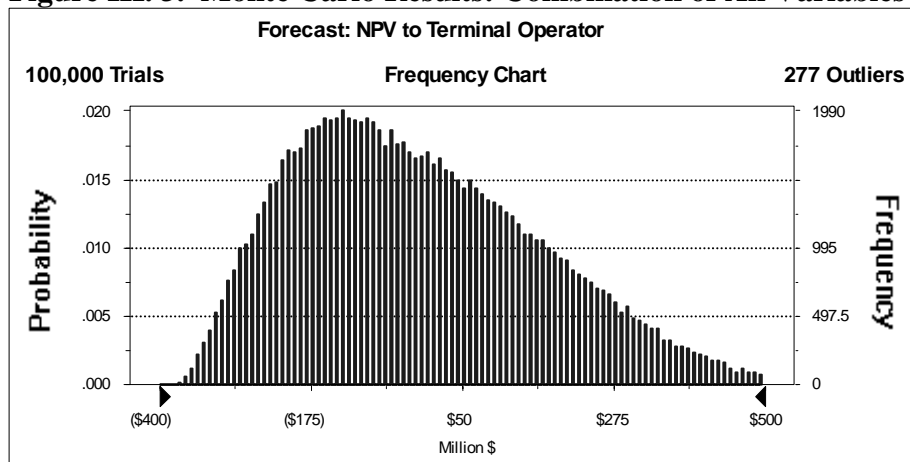
Variable	Range Used	Expected Value (\$million)	Standard Deviation (\$ million)	Probability of NPV<0
1. Initial Moves per Year (000)	200-400	-38	\$154	61%
2. Growth Rate in Moves	4% – 8 %	\$16	\$89	47%
3. Costs	-10% to +10%	\$10	\$13	23%
4. Productivity (Moves/hour/crane)	40 – 50	\$7	\$ 26	37%
Combination 1-4	NA	- \$ 14	\$181	57%

The combination case results (Fig. III-3) indicate an expected value of -\$14 million (Table III-5), a 57 % chance of a loss, and a small chance of a loss of up to NPV° \$400 million). It follows there is a 43% chance of a gain. Also, there is a 25 % chance of a gain exceeding \$109 million, and a small chance of a operator gain of over \$200 million.

Table III-6. Monte Carlo Results Combination of the Variables

Statistics:	Value
Trials	100,000
Mean	(\$14)
Median	(\$38)
Standard Deviation	\$181
Variance	\$32,920

Figure III. 3. Monte Carlo Results: Combination of All Variables



III. E. IMPORTANT QUALIFICATIONS, COMMENTS AND CAVEATS

The range of assumptions used for our illustrative case study includes startup moves (200,000 – 400,000) that are lower and higher than the start up estimates of 250,000 moves in RKJA (2000) and used by Quonset Point Partners (QPP). Also, we assume a steady growth rate ranging from 4 % to 8 %, while RKJA, for example, assumed more rapid growth in early years, which has important implications for their estimated NPV^o, since revenues received in the early years of a project have a bigger positive effect on NPV^o than later revenues.

Few ports have attained the high start up volume envisioned here. To achieve and handle this high and rapidly growing volume of cargo movements through the port, several very optimistic assumptions must be met. For example, the RKJA analysis assumes (1) an Automated Terminal Concept is employed using a state-of-the-art (50 box moves per hour) gantry crane operation and (2) an efficient system for handling and storing boxes. RKJA also assumes that there exists (3) an efficient intermodal system with double-stack train capability for distant markets (e.g., Mid West), and (4) road/highway access to targeted, Northeast markets are in place, as planned. RKJA also assume (5) that chronic labor problems do not arise that would cause delays or raise questions of reliability, which would adversely affect shipping lines' perceptions of the port. *These are critical assumptions for the success of a terminal, and our results show the negative financial consequences, if these optimistic assumptions are not met (see Table III – 3).*

We reemphasize that we have not done an independent estimate of container port transportation demand, and use the numbers given above merely as an exercise to illustrate the sensitivity of NPV^o to changes in start up TEU and the growth in moves over time. We are attempting to estimate container port transportation demand for East Coast ports using the model described in Chapter II and other approaches, as appropriate. Our other sensitivity analyses involving a terminal operator's productivity and costs (given in the Monte Carlo case) for the most part all differ from, and bracket those, in RKJA and the earlier Quonset Point Partners.

In sum, our assumptions are just that — assumptions — made for the purpose of illustrating our framework and examining how different assumptions and judgments affect container terminal profitability. To illustrate our model, we simply bracket published estimates made by others in order to examine the sensitivity of the NPV^o to different assumptions for key variables for a hypothetical container terminal.

Only selected sensitivity analyses are done here, and we recognize that many other important factors can and should be examined in more detail than was possible in this Year One report. Our model – updated and refined as appropriate -- will eventually be available to the public, government, businesses, and interest groups who can do their own “What if?” analyses through the state-of-the-art Policy Simulation Lab at the new URI Coastal Institute.

It is important to remind the reader about several uncertainties. For example, it is unclear whether and to what extent the terminal operator would pay for substantial dredging costs, or for site preparation costs in addition to those reflected in the RKJA spread sheet and described in RKJA (2000). Our results above assume that the terminal operator pays no dredging costs; this assumption shows a more favorable NPV^o than would including such costs.

Further, it not clear what financial arrangements might be made between the state and the operator, including policies that might be adopted should the minimum scale of activity at a terminal not be attained. For example, our estimates given above include the assumption that the (out-of-state) private operator pays the state \$75 per move through the port, up to 500,000 moves per year. This is a major cash outflow for the operator, as much as \$37.5 million per year, and potentially a substantial benefit to the state (see Chapter V). A downward adjustment of this payment would raise the NPV^o for the private operator, but a big drop in fees would substantially decrease the benefit to State residents (see Chapter V). This illustrates the tradeoffs policies can have for state residents and private terminal operators. Our framework and model, when refined appropriately, will allow us (and later, other users) to assess these and many other policy issues.

We also note that the wage used for dock workers in our estimation of NPV^o, \$48/hour, may be higher than would be paid in practice. Use of a lower wage will raise NPV^o. However, lower wages reduce the benefit to the state (see Chapter V)). Again, we hope to refine these numbers as additional information from more specific port proposals become available.

Finally, we must recognize that an operator can take actions to avoid losses and improve profitability, e.g., engage in adaptive behavior, in ways that the above model does not capture. For example, if moves through a port are lower than projected, an operator could defer investment in additional superstructure (e.g., cranes) or other facilities, by that avoiding or reducing a loss. Our results given above do not allow for such flexibility.

For all of the above (and other) reasons, the results described earlier in this chapter must be viewed as only illustrative and are subject to revision and much refinement when additional details become available for a proposed terminal.

APPENDIX

ASSESSMENT OF CONTAINER PORT OPERATIONAL UNCERTAINTY: APPLICATION OF AN EVENTS MODEL

III.A.1. INTRODUCTION

The discussion in the Chapter III, above, focuses on financial considerations and uncertainty with respect to NPV^o. As part of our Year One work, we also initiated a study of the operational uncertainties faced by container port operators. Here, we describe this work.

In the context of a simulation model, a port is an example of a *discrete* system as state variables, for instance, the number of ships in the port, change only when a ship arrives or departs. In other words, the system state changes when an *event* such as ship arrival or departure occurs, and so it is called *event simulation* model. And a port is likely a *dynamic* and *stochastic* system as it evolves over time and also contains one or more random variables such as arrival times and service times.

We have been developing an event simulation model for port development purpose, based on the know-how that we previously developed (Chang, 1995 and Chang, 1999). The *event simulation* model is basically designed and used for estimation of ship turnaround times and cargo movements in a port and inland transportation as part of investment appraisal of port expansion. In other words, the simulation model should estimate ship turnaround time, cargo movement time of an existing system, and proposed expanded systems of various alternatives, respectively. The improvements of the port developments (i.e., the differences in the turnaround times between the existing system and the expanded systems) could be evaluated from the viewpoint of private entities, a state, and the nation.

III.A.2. LOGIC OF THE MODEL

The logic of the event model, in general, can be divided into three parts: initialization, iteration, and output (Figure III.A.1). The initialization part deals with data input and parameter input such as number of replications, simulation run period, parameters of input random distributions, and the initialization of variables, including initialization of a random generator by specifying a new seed in order to prepare the calculating process.

The iteration process part generates each ship's arrival, assigns a berth for the ship based on the berth assignment policy of the port, generates service time also by a random generator for the ship in the assigned berth, and finally calculates the departure time.

The output part should show us the individual ship's arrival time, berthing time, departure time and waiting time in the queue and the system. It also should show the summation of the waiting time, mean value and standard deviation, and the relative and cumulative frequencies of waiting time distribution in the system as well as in the queue.⁹ Likewise, along the inland transportation network, the same process of input, iteration and output should be carried out in the model.

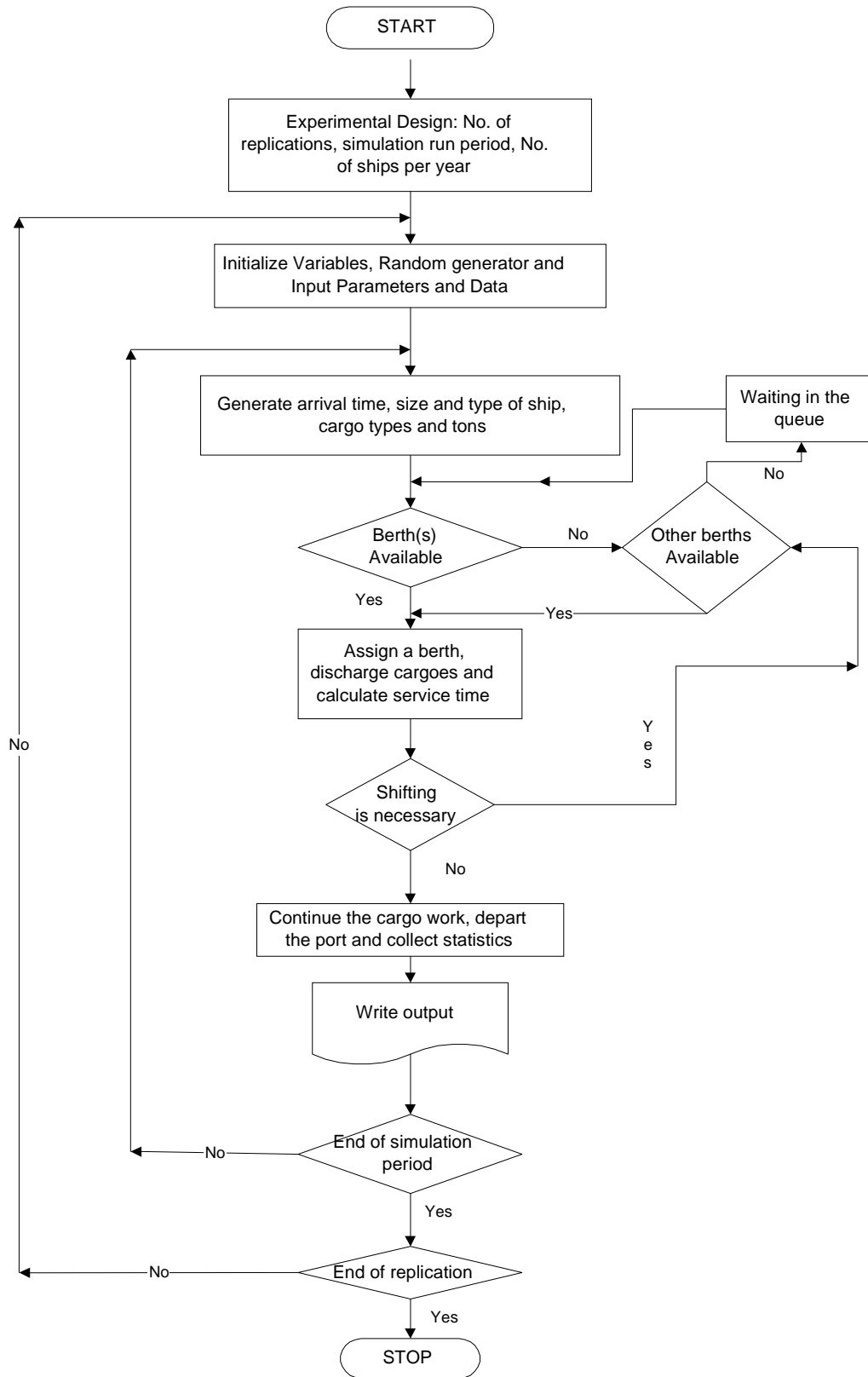
This process is continued until the final ship finishes the stevedoring work and departs the port during the necessary simulation run period and also until enough replication can be made to draw a statistical conclusion on the output. In total, the same process of ship maneuvering in the port is repeatedly simulated (number of ships calling at the port annually * simulation run period * number of replication).

This general process of a ship in a port network can be modified when a specific situation in reality is considered, and so the process becomes more complicated than the general process. For instance, even after a ship is berthed while loading or discharging cargoes, sometimes it can move to another berth to give way to another ship for her preoccupied berth. The specific design of these unusual cases or different operational policies of port authority can be better analyzed with simulation models than any other models.

Building a typical discrete dynamic stochastic simulation model takes the usual steps of: (1) formulate problem and plan the study, (2) collect data and define a model, (3) test input distributions, (4) construct a computer program and verify (called *verification*), (5) make pilot runs, (6) *validation* of model, comparing the model output with actual system, (7) design experiments, (8) make production runs, (9) analyze output data, and (10) document, present and implement results (Law and Kelton (1991, pp. 106-109). A detailed model building process of a port is presented by Chang (1995).

⁹. *Waiting time in the system* means the duration that ships spend in the port, that is, ship turnaround time and *waiting time in the queue* means the duration that ships have to wait in the queue until berths are available. See Hillier and Lieberman (1990) 593-600.

Figure III.A-1. The Logical Process of Simulation



III.A.3. IMPLEMENTATION OF THE EVENT MODEL FOR CASE STUDY

A pilot event simulation model was built. To implement and test the model, detailed data were required. For purposes of this illustration, we used design and productivity information given in RK Johns & Associates (2000), as this is the only data available at this point. Basic assumptions of the plan are presented in Table III-2 and Figure III-1. To build the event simulation model, detailed assumptions and scenarios were taken directly from the report or derived therefrom. Basic assumptions of the model are as follows:

- (1) Basic layout plan: two berths are operated from the beginning years for the first phase and each berth is equipped with two gantry cranes. Container box is moved mainly by Rail Mounted Gantry cranes between berth and storage yard and supplemented by Yard Conveyors, Truck load/ unload devices. Gate provides ten lanes in the initial years. The space and distance in the terminal is taken from the report, i.e., the terminal area is about 270 acres and the distance between the berth and storage yard is 333 feet, etc.
- (2) Parameter assumptions: Each RMG moves fifty container boxes per hour and therefore, per box moving time is 0.02 hour. The whole terminal works forty-two hours per week as in the report. We assume that the terminal works five days per week from Monday to Friday and thus, the daily operation will be 8.4 hours on and 15.6 hours off (42 hours/5 days). The storage yard is 23 acres and simultaneous storage capacity is 18,750 boxes as in the report and the yearly capacity is 1.5 million boxes. Fifteen to eighteen ships arrive in the terminal per week as in the report. Accordingly, ships arrive in the uniform distribution of $U(8,12)$ between 8 and 12 hours. The first year handles 250,000 boxes as in the report, and from this number of boxes and the ship arrival frequency, each ship generates 267 to 320 boxes per ship. Thus, the model generates the box based on the uniform distribution -- $U(267,320)$. Likewise, each year's ship container boxes are generated from the relationship between ship arrival frequencies and yearly throughput. (Other detailed parameters were needed, although their explanation is omitted here for brevity.)

From these assumptions and parameter values, the event simulation model (QPP model) using ARENA software was built through pilot running, verification and validation, production run and output analysis processes. Basically, the model shows vessel arrival, berthing, container work between ship and dock side, then moving boxes to yard, yard storage and finally leaving gate. As the model runs, we can see animated movement of ship arrival and departure, crane work and box movements. The terminal was designed to guarantee four days dwell time in the terminal. The gantry crane's productivity and other operational aspects are likely key issues, and hence the simulation model was focused on these operational aspects.

III.A.4. RESULTS

The results of the simulation model pilot study are presented taking the outputs of two years-- year 1 and year 5. Year 1's container throughput is 250,000 boxes and year 5's is 500,000, and each berth is equipped with two rubber tired mounted gantry cranes (RMGs) for this period. Year 5's simulation output is presented in figure 8. ARENATM generates various detailed outputs, and each movement can be traced to check the validity, but due to space constraints, we present only the summary of the year 5's output.

From the year 5's output, we can see that ten replications for the whole year five were made (Table III.A.1). This means that we ran year five's production ten times. We checked duration of vessel turnaround time, box dwell time in the terminal, ship's waiting time for a berth, number of ships arriving in the terminal, and number of boxes handled. The summary table shows that the vessel turnaround time is 18.011 hours (see TAVG (DEPARTURE_TA) identifier) and boxes remain in the terminal for 15.924 hours (see BOX DEPART_TA identifier). Per vessel waiting time for a berth is 1.59 hours (see BERTH1_Q QUEUE identifier).

The output also shows vessel turnaround time's standard deviation – 5.6 hours (see TSTD identifier). We can see that vessel can turn round within one day, and container boxes can also dwell within one day. In sum, the simulation can show the whole probability of vessels movement and cargo movement, and indeed, it can show as much of the detailed operational picture as analysts wish in distributional form. In other words, the model shows the *risk* profile of the project.

According to yearly cargo throughput, the first year's throughput is doubled in five years and the terminal assumes to use same capacity of berth and cranes in terms of the numbers (two berths and four RMGs). The success of the port plan is believed to lie in faster turnaround time of ship and cargoes. So we checked the change of ship turnaround time as well as boxes between year 1 and year 5. The results are shown from Figure III.A.2 – 5.

Table III.A-1 Simulation Results of 10 Replications for Year 5 QPP Model.

ARENA Simulation Results
Young-Tae Chang - License #9810752

Output Summary for 10 Replications

Project: QPPyear5move50bo	Run execution date : 2/23/2001
Analyst: YT Chang	Model revision date: 2/23/2001

OUTPUTS					
Identifier	Average	Half-width	Minimum	Maximum	# Replications
TSTD(DEPARTURE_TA)	5.6063	.04188	5.5258	5.7471	10
TAUG(BERTH1_Q QUEUE TI	1.5867	.05169	1.4684	1.6881	10
TAUG(BOX DEPART_TA)	15.924	.08968	15.740	16.133	10
TAUG(DEPARTURE_TA)	18.811	.07740	18.635	19.055	10

Simulation run time: 14.70 minutes.
Simulation run complete.

Figure III.A.2. Ship Turnround Time of Year 1 at QP

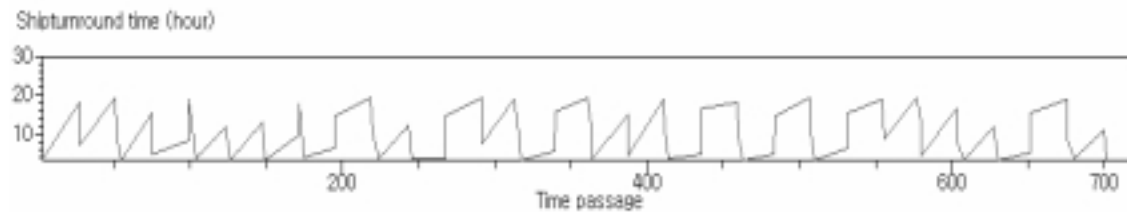


Figure III.A.3. Ship Turnround Time of Year 5 at QP

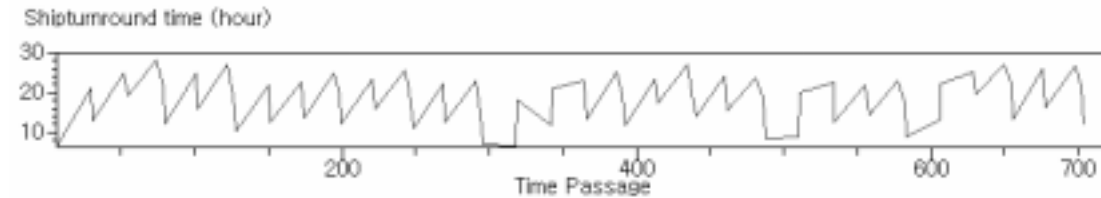


Figure III.A.4. Box Turnround Time of Year 1 at QP

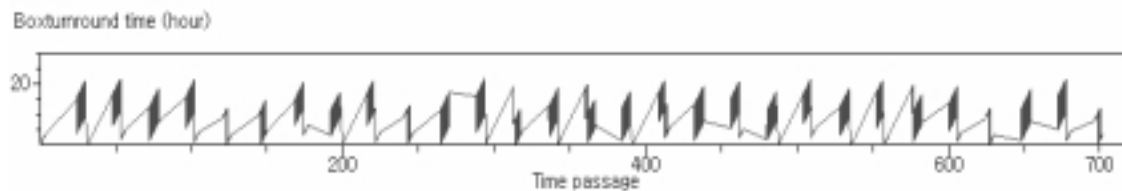
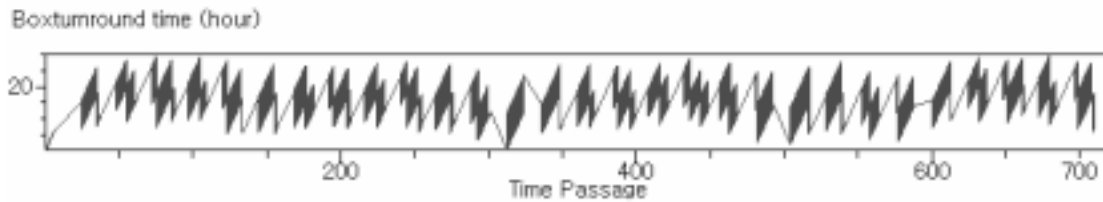


Figure III.A.5. Box Turnround Time of Year 5 at QPP



We plotted the turnaround times for a one-month period. The figures show that year 1's turnaround times of both ships and boxes are mostly less than twenty hours and year 5's less than thirty hours. They seem to be at a satisfactory level as the consulting company's estimates, based on the assumptions of the crane productivity and other parameters. These turnaround times fall in the category of a good hub container port. Contemporary good hub ports usually place three gantry cranes per vessel and in some cases, even four or five cranes, depending upon the urgency of cargo work and ship schedule. The consulting team's report places two RMGs per vessel, assuming fifty moves per crane per hour.

We also checked the change of busy rate of RMGs from year 1 to year 5. The results are Figure III.A.6 - 7. ARENA shows the crane's busy rate as the ratio of total used time to total available time and so per crane busy rate should be divided by the number of cranes – in our case by two cranes. From the figures, we can see that year 5's busy period gets wider than year 1. The gap between the bars in the figure means off-hours of the terminals. From simulation output of year 1 and 5, the busy rate of berth increased from 50 % in year 1 to 83 % in year 5, and crane's busy rate increased from 29 % in year 1 to 59 % in year 5.

Figure III.A.6. Busy rate of Gantry Crane of Year 1 at QP

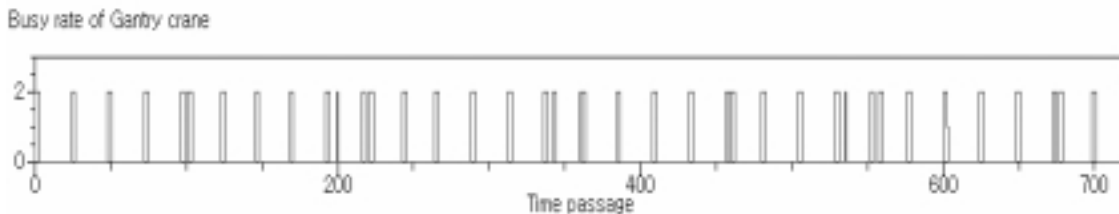
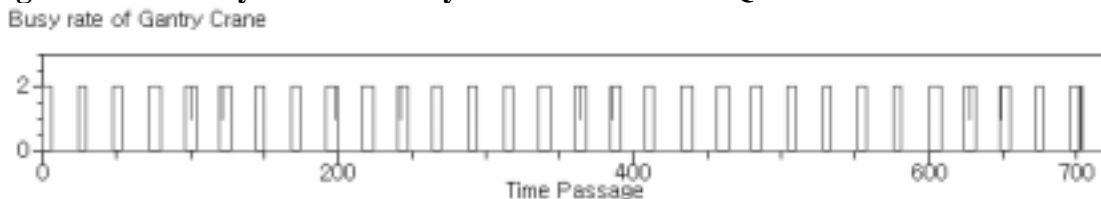


Figure IIIA.7. Busy rate of Gantry Crane of Year 1 at QP



Finally, we checked the 95 % confidence interval of vessel turnaround times of year 1 and year 5. The results are shown in Figures III.A.8-9. We can check the risk profiles of decision variables and output variables in statistical form, i.e., confidence interval. This risk profile can be transformed or incorporated into another stage of study- -economic analysis or environmental impact study. As explained, the risk of a project is defined as the case of which we know the probability. By using an event simulation model, we can grasp the risk profile by being able to have the probability distributions of the variables concerned. Chapter III discusses how the risk profiles can be transformed into investment analysis and other studies.

Figure III.A.8. 95% Confidence Interval of Ship Turnround Time in Year 1 over 10 Replications

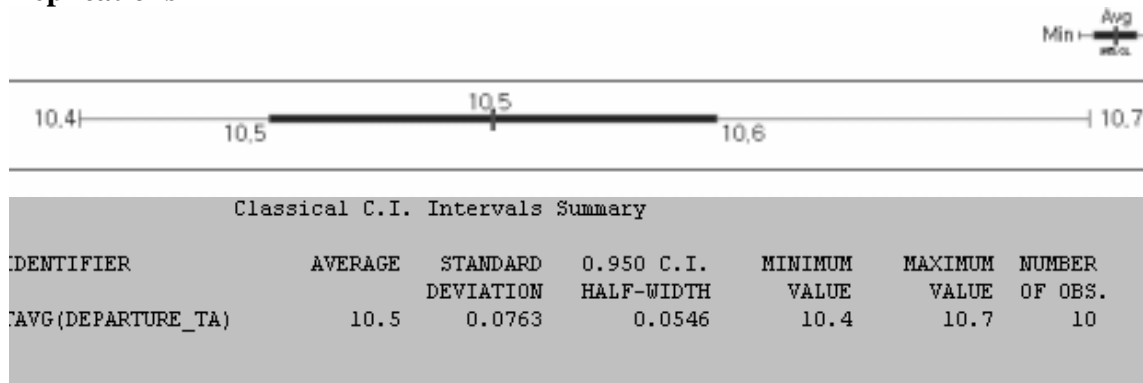
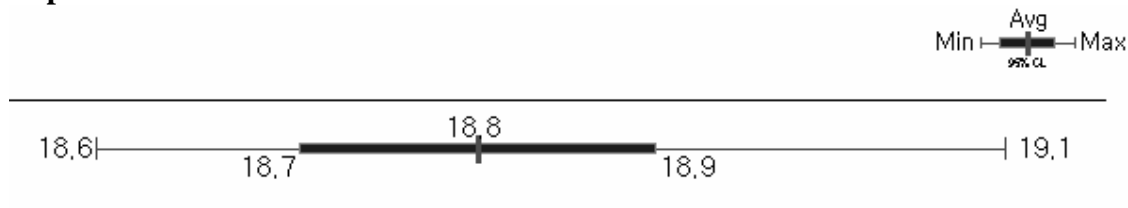


Figure III.A.9. 95% Confidence Interval of Shipturnround Time in Year 5 over 10 Replications



IV. PERSPECTIVE ON EXTERNALITIES IN PORT DEVELOPMENT

IV. A. INTRODUCTION

Environmental issues – real and perceived -- are a major factor affecting port decisions throughout the US. External costs (or “externalities”) are *uncompensated side effects* on third parties due to actions or activities by businesses or individuals. These represent a classic case of market failure in that sources of an externality do not take into account the full consequences their actions have on others. Failure to recognize external costs has several effects. The true (societal) costs of an activity are understated, prices may be lower than they would be if all costs were considered, and the source of the external cost and its customers get an implicit subsidy from those who bear the external cost.

External costs reduce the net benefits that port development can provide to state residents or the nation. On the other hand, external benefits could occur if, for example, movement of cargo by vessel substitutes for truck traffic and by that, reduces congestion and air pollution. To fairly account for the full consequences of port development, both negative and positive external effects should be considered in any objective assessment of the consequences of proposed port development.

Environmental concerns with port development differ of course in their particulars between ports. This Chapter provides a *generic* discussion of environmental issues often raised in connection with port development. Examples of potential environmental costs that might be relevant to our illustrative port case study and methods to quantify such costs are given in Chapter V.

Generally speaking, port development-related environmental issues include those resulting from dredging and modification or loss of shorelines and sub-tidal areas; air and water quality issues; road congestion; concerns with noise and loss of area amenities; possible introduction of non-indigenous species, and other issues described more fully below. To list environmental concerns, of course, does not mean that all of these concerns will in fact prove to be important in a specific case, nor does it mean that all issues are equally important. The scale and type of port activity, the relative role assumed by rail versus trucks to move containers, the attributes of the affected areas, as well as actions that can be taken by developers and government agencies to avoid or mitigate potential adverse effects all influence whether, and to what extent, a particular concern is a significant external cost. Further, port development could actually reduce some environmental costs, such as when use of vessels to deliver cargo reduces road traffic and associated air pollution and traffic, as noted.

This chapter provides a perspective on external costs from container port development. It was not within the scope of the first year of study to examine all prospective, port-related environmental concerns. Instead, we restrict ourselves here to a much more modest effort in which we (1) explain the importance of efforts to quantify potential external costs, (2) list potential external costs based on visits to ports throughout the US during the first year

of our project and review of the literature, and (3) present a case study and other examples to illustrate measurement of selected external costs. Finally, we note plans to refine and extend our economic analysis of environmental issues. We emphasize that much uncertainty surrounds potential external costs and many measures can be and are taken to reduce these potential costs. Hence, risk and uncertainty are important concerns for external costs, just as they are for private terminal operators and for states.

IV. B. IMPORTANCE

Efforts to estimate the potential environmental costs of port development are important because proposals to develop ports typically are subject to intense public debate often within a legal, quasi-legal, and political process. This process involves an Environmental Impact Statement, public hearings, and reconciliation of interest group concerns. In our numerous interviews with senior port authority officials throughout the US, from Long Beach to New York/New Jersey, and from Vancouver to Charleston, environmental concerns were clearly identified as a major issue strongly affecting the planning, scale, and timing of port development.

Failure to resolve environmental disputes early on can cause substantial delays, costly modifications of proposals, or very expensive mitigation actions--and often, all three. This influences the scale and design of proposed port projects as well as their economic and perhaps political feasibility. For example, the Port of New York and New Jersey has been stymied in its efforts to deepen channels due to the lack of a disposal site or beneficial uses for dredged materials, substantial delays due to limits on periods where dredging will be allowed (dredging windows), and the resulting high costs of dredging (a billion dollars or more).

In this adversarial setting, careful and objective analyses of the potential economic costs of environmental issues can contribute to improved port development decisions in several important ways. First, providing monetary estimates of environmental costs puts all benefits and costs on the same footing. This helps make comparisons between environmental costs and hence places environmental costs in some perspective. Unless such quantification is attempted, perceptions of potential environmental costs may be grossly understated or overstated with little or no objective data to weigh the relative significance of these concerns.

Quantifying potential external costs in monetary terms also may contribute to port decisions by providing information that interested parties and decision makers can use to (1) direct scarce resources to study further or ameliorate the most important concerns, (2) help evaluate proposals to select the type and scale of mitigation actions, and (3) contribute to selection of a preferred site for marine disposal of dredged sediments. Quantification of external costs also can (4) contribute to an evaluation of the efficacy of using measures, such as dredging windows, in order to avoid some marine environmental costs influenced by seasonal factors, e.g., spawning periods for fish, or critical periods for marine mammals or seabirds. More generally, expanding the range of potential

environmental costs and benefits can improve benefit-cost analyses of proposed developments.

In sum, objective studies of potential external costs and benefits can better inform public debate in many ways. However, even the best technical analyses will be of limited use unless the results are presented in ways that facilitate use by various stakeholders, a point we return to briefly at the end of this chapter.

IV. C. ISSUES AND CONCEPTUAL FRAMEWORK

Specific environmental issues vary between ports, but generally involve concerns about the potential loss of environmental and natural resource services and potential risks to the public's well being due to several causes. *Generic*, potential issues at container ports include:

- dredging and dredge disposal
- loss of wetlands, shoreline, and bay bottom due to fill and construction
- air emissions from vehicles and to a lesser extent, vessels and diesel powered locomotives
- offsite, peak-use road congestion
- traffic delays at offsite rail crossings
- additional maintenance due to accelerated wear and tear on roads
- loss of open space amenities in nearby communities
- light and noise externalities for residential communities near ports and, in the case of noise, along routes heavily traveled by trucks
- localized water pollution from terminal storm water runoff
- physical interference with seasonal fish spawning runs
- introduction of non-native species in ballast water by additional vessel visits, and
- conflicts with commercial fishing and recreational uses of area waters.

Sources addressing these potential issues include MARAD (1994a and 1994b), Colorni *et al.* (1999), Federal Register (1997), Grigalunas *et al.*, (2000); Grigalunas, Opaluch, and Luo, 2001, WADOT, 1999; Carlton, et al., (1995); Smith, et al., (1996).

As is always the case, it is easy to list *potential* environmental issues, but much more difficult to assess their significance. Yet, quantification is very important for the reasons given above.

To provide credible estimates of port-related environmental costs in particular cases, several challenges must be met. One involves quantifying each of the relevant, potential environmental effects. To do this, cause-and-effect links must be established between (1) an environmental *stressor* (e.g., air pollution, noise, loss of open space amenities); (2) *exposure* of resources or people to the stress; (3) *injury* or harm to resources or people

exposed, (4) change in *behavior* (e.g., avoidance); (5) loss in the quantity or quality of *services*; and finally, (6) the loss in *economic value* experienced by the public.

Links (1) - (3) fall in the realm of the natural sciences, underscoring the need for an integrated, interdisciplinary framework in many cases. Further challenges arise from the fact that the appropriate environmental effects to be considered in public policy discussions are the *net* effects, that is, the environmental consequences that will be realized with, versus the situation without, port development. A second set of challenges stems from the *non-market* nature of external costs and the resulting difficulties in estimating their monetary value (steps (4) - (6), above), which requires use of non-market valuation methodologies (e.g., Kopp *et al* 1993, Freeman, 1993; Grigalunas and Congar, 1995). Although difficulties remain, major advances have been made in non-market valuation over the past two decades, as the examples given later in this chapter illustrate. Further, we argue that perfect data rarely, if ever, are available, in any field but even imperfect information, judiciously used, can contribute much to inform policy debates.

Other, related problems arise with assessing the cost-effectiveness as well as net benefits of mitigation measures (e.g., restoration to offset lost wetlands or installation of noise-dampening structures to lower noise exposure) or other policies, such as use of dredging windows, often proposed to compensate for, or to avoid, external costs (Grigalunas, Luo, and Opaluch, 2001; Mazzotta, Opaluch and Grigalunas, 1994). Finally, even the best studies will be of limited practical use unless they can be presented in ways that engage the attention of stakeholders, as noted.

At a conceptual level, we want to estimate the public's economic value (here, cost) of the *incremental* environmental stresses resulting from port development. We recognize that a total valuation approach might be used in an attempt to capture all economic values, including passive use values, in a single study. However, the complicated nature of the many issues involved, and the desire to have separate estimates of different potential losses that might serve as a basis for mitigation or compensation decisions for each resource issue argues for use of a variety of valuation methods, as described in the text (see, e.g., Johnson, et al., 2001). Further, estimation of total value remains more problematic than the estimation of the individual use values we consider in this report. The potential for mistakenly double counting losses should be recognized.

Methods to estimate economic value depend upon the natural resource service or issue being considered (e.g., Freeman, 1993). Briefly, if the issue is the effect of port-induced development on the lost value of the services provided by fishing grounds or wetlands, the productivity approach can be employed, as we show below. This approach estimates the loss in the value of annual catch of fish, shellfish, and crustaceans (mainly lobster in our example) due to port development. In other cases, for instance valuing a loss of area scenic amenities, such as open space for neighboring property owners, then revealed preference approaches are appropriate. These approaches capture individuals' economic value through people's behavior in markets, as found in changes in local property values or by changes in the participation in outdoor recreational activities, for example.

On the other hand, for assessing loss of open space or other natural resources that are enjoyed by the public in general (i.e., public goods), survey-based, stated-preference methods are needed. An example given below illustrates this method where the public is found to have clear preferences for environmental amenities like open space, wetlands, and unpolluted water. Lastly, for mitigation, estimates of economic value or use of the habitat equivalency approach may be appropriate (e.g., Mazzotta, Opaluch, and Grigalunas, 1994). A somewhat extensive case study and brief examples, given below, make the general discussion in this section more concrete.

IV. D. CASE STUDY AND EXAMPLES

IV. D. 1 Case Study: Economic Cost to Fisheries from Dredge Disposal

Here we illustrate the estimation of one potential environmental cost of port activity -- the costs to fisheries of marine disposal of clean dredge sediment -- using the productivity approach. This is an interesting case in that (1) it is a common and often controversial issue in port development, and (2) it raises interesting methodological issues. The discussion that follows draws heavily on Grigalunas, Opaluch and Luo (2001a)

First, we provide brief background on the issues involved and the rationale for the model used, followed by a short discussion of the data and assumptions employed. In this case study, many uncertainties were faced. Recognizing these uncertainties, we deliberately adopted a conservative (i.e., overstated) cost approach, a standard practice in policy-relevant research. Next, the results are summarized, together with several sensitivity analyses done to reflect further the uncertainties involved.

We emphasize that (1) our illustration is for marine disposal of *clean* sediments and (2) we also do not include the transportation costs of moving dredged sediments to potential disposal sites, a consideration which may influence site selection. Also, not included here is any discussion of the potential costs to fisheries (especially sensitive larval stages) of the dredging itself. Recent efforts by Grigalunas, Opaluch and Luo (2001b) address this latter issue and will be described in later work.

IV. D.1. a. Background

Our illustration concerns proposed dredging and marine dispose of some 5.1 million cubic yards of clean sediment from in and around the Providence River and Harbor in Rhode Island, USA (Grigalunas, Opaluch, and Luo, 2001). Seven potential disposal sites are being considered by the responsible agency, the US Army Corps of Engineers (COE), three in Narragansett Bay and four in Rhode Island Sound. Each of the sites differs with respect to its location, bathymetry, water depth, and with regard to the abundance of fish, mollusk, and crustaceans (primarily lobster) and their age structure. Due to differences in the bathymetry, the mound created by sediment disposal preliminarily has been estimated to cover from 121 to 215 hectares, depending upon the site (L. Oliver, COE, personal

communication, August 15, 2000). Disposal at a site may cause mortality to legal size and juvenile fish and may also have adverse ecosystem effects. Losses could be borne by recreational users and commercial fishing interests.

In short, losses could be short-term or long-term, offsite as well as on-site, and may involve non-market, recreational losses, in addition to market-valued losses to commercially harvested species. Ideally, any assessment of the economic costs due to marine disposal of sediments would capture all of these effects and would be done for each site, recognizing the many differences that exist between sites.

The cohort-type or age-class model we use (Ricker, 1975) seems appropriate for this problem since the model can capture the three elements of lost catch mentioned. This can be very important, for example, if an area primarily serves as a nursery, so that short-term fishing losses may be negligible, but the long-term loss in catch might be significant. Without a cohort-type model, such long-term effects may be missed, or may have to be addressed in an *ad hoc* manner.

IV. D.1. b. Concepts and Model

We seek to estimate the losses for commercial fisheries (economic rent) and for recreational users (consumer surplus) due to reduced catch. These losses are assessed over time, until the affected species recover, and the estimated annual monetary values are discounted to arrive at the present value of the economic costs for each site. This value is the potential loss in the asset value of each site due to the lost productivity at the disposal site (Freeman, 1993; Kopp *et al*, 1993; Grigalunas and Congar, 1995). Recognizing the many uncertainties involved, we use assumptions that overstate costs and carry out a series of sensitivity analyses, described below.

Three components of fishery losses due to sediment disposal are estimated: short-term effects, long-term effects, and indirect (ecological--food web) effects. Standard methods are used for estimating each of these components of losses (EAI & ASA, 1987; Grigalunas *et al*, 1988). Specifically: *Short-term effects* are economic losses due to reductions in catch during the disposal period as a result of mortality to adult fin fish, mollusks, and crustaceans. In keeping with our overstated cost approach, disposal of the large volume of sediments involved is assumed to cause 100 percent mortality to all biomass in the disposal area over the entire 18-month disposal period. Short-term lost or foregone catch for a species thus is equal to the fishing mortality rate (F) times the adult biomass (B) for each species for the affected area integrated over the disposal period.

Long term effects are economic costs due to foregone catch of each species over the period of recovery of the population, including losses due to mortality to adult fish, juveniles, and young-of-year. Long-term losses are determined by simulating recovery of the population following the disposal period using a Beverton-Holt, age-class model (Ricker, 1975). The model simulates the mortality and growth of each age class of the population for each species, and calculates the lost catch during the recovery period.

Indirect (food web) effects are the economic losses from reduced commercial and recreational catch due to impacts of disposal on food resources. Losses of food resources are translated to lost biomass of commercial and recreational species, and then to reductions in catch. Following (ASA *et al*, 1996), we use a proportionality rule, whereby the fraction of predator species biomass lost equals the fraction of prey lost due to disposal. Given our use of an overstated cost approach in this paper, we assume that *all* prey at a site is lost due to disposal of sediments at the site.

For short and long term effects, a Beverton-Holt approach (Ricker, 1975) was used to model the number and the weight of individuals for each age class. Before the age of recruitment to the fishery, the number of individuals in an age class declines due to natural mortality, M ; after recruitment, the number declines due to both natural and fishing mortality, F . Total weight of each year class of a species at time t , W_t , is a function of number of surviving individuals and their length, which is a function of time up to a maximum life span, t_{\max} . An individual's weight is a function of length. Catch is the species-specific fishing mortality rate times the biomass, and total catch from legal age size class k through its remaining life span is:

$$C_k = \sum_{t_k}^{t_{\max}} FN(t_R)W_t(1 - M - F)^{(t-t_R)} \quad \text{for } k > R \quad (1)$$

where t_{\max} is the maximum age for the species, and:

$$C_k = \sum_{t_k}^{t_{\max}} FN(t_R)W_t(1 - M - F)^t \quad \text{for } k \leq R \quad (2)$$

Recovery is presumed to start at the end of the 18-month disposal period. Recovery for each age class occurs in sequence over time as the initial age class matures and grows, with full recovery of the population occurring after t_{\max} years. The loss during this recovery period is the long-term effect, that is, it is an estimate of what would have been caught from age classes lost during the recovery period in the absence of disposal. Note that potential disposal sites were screened by the COE so that the material being disposed of is similar to the sediments at each site, by that facilitating recovery of the same species at the site.

For each species, estimated lost catch is divided into either lost commercial or lost recreational catch using estimates of commercial and recreational rates by species category. Thus, the overall fishing mortality rate (percent of fish caught per period), F , can be decomposed into a commercial and recreational part: $F = F_{\text{COMM}} + F_{\text{FREC}}$. The lost catch is then valued using appropriate commercial or recreational marginal values, as described later. An important assumption here is that fishing effort is assumed not to change due to disposal. This assumption is reasonable, given the relatively small area impacted (121-215 hectares) and the fact that the *annual* lost catch of any species is quite small and, for mobile species, is widely dispersed over space.

Commercial values used in the model are the 1998 dockside prices for each species and were obtained from the National Marine Fishery Services (NMFS, 2000). Details are given in (Grigalunas, Opaluch, and Luo, 1999). Assuming effort is constant, market prices represent the marginal economic loss from reduced commercial landings. The estimate of lost recreational values also uses marginal values, as we describe later. All monetary values are in 1998 constant dollars, and we use a discount rate of 6.87%, the rate designated for use by the COE and reflects the real, federal (risk free) long-term cost of borrowing capital.

The indirect effect measures biomass not produced as a result of a loss of lower trophic organisms, which serve as food resources for commercial and recreational species. Following Applied Science Associates, Inc., *et al.* (1996), the food web loss for commercial and recreational species is estimated using a simple assumption that loss of biomass for consumer species is proportionate to losses of prey production. However, no food web losses would occur if consumption of all food resources by predator species occurs on-site, since all predator species within the disposal area are also lost due to disposal. Thus, if all lower trophic production is consumed on site, the assumed total loss of all consumer species negates food web losses, so that adding indirect losses to direct losses double counts losses from disposal.

However, off-site food web losses *may* occur if food resources are lost to consumer species outside the disposal area. For example, consider food resources that are transported by currents. All harvestable fish production within the disposal area is lost, and additional production is lost outside the disposal area due to loss of food resources from the disposal area. Hence, there may be a net loss in production of commercial and recreational predator species outside the disposal area due to mortality to food resources within the disposal area. Consistent with our intent to overstate losses, we assume a net loss in lower trophic production export of 50 percent of the food resources for the proposed disposal sites. Our assumption of proportionate losses of consumer species implies that the off site food web effect equals 50 percent of the biomass in the disposal area for all commercial and recreational species in the adjacent area. Food production is assumed to fully recover immediately following the end of the 18-month disposal period.

Biological Data. To implement the above model, the biological information required concerns the abundance of each species (in grams wet weight) at the disposal sites and species-specific, life history parameters for growth in length, weight as a function of length, time to recruitment (i.e., entry) to the legally harvestable fishery, maximum age for each species, natural mortality, and fishing mortality (commercial and recreational) (Details are given in Grigalunas, Opaluch, and Luo, (1999)).

Two principal sources were used for biological information. One was the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME) published by the U.S. Department of the Interior (Applied Science Associates *et al.*, 1996). The model is incorporated in federal regulations and has been subject to an extensive public review process (NOAA, 1996) Information from this

source includes, for each species group: average biomass per unit area, natural and fishing mortality rates, growth, weight as a function of length, years to recruitment, and maximum life. Of course, data in the NRDAM/CME are averages and hence are only approximations.

The second important source of biological data are the Environmental Impact Statements (EIS) prepared for the Providence River dredging project by the COE (1998, 1999). Key information from these sources includes sampling data for finfish, lobster, and mollusks for all potential disposal sites. These data show considerable variability in biomass, by species, among sites. Unfortunately, the data in the EIS is for Catch Per Unit Effort (CPUE), for example, catch per tow for finfish or catch per trap for lobster, and not biomass per square kilometer, which is needed in our model. Thus, we use data from the NRDAM/CME to provide estimates of biomass per unit area, and use CPUE data from the EIS to calibrate the data at each site. Sampling data reported on in the COE EIS (1999) found many species of fish at the disposal sites. However, a relatively small number of commercial or recreationally important species dominate the sampling data: lobster, quahogs, flounder, tautog, and Atlantic herring. Hence, the bio-economic analysis focused on these species. Remaining species were aggregated into an “All Other Species” category.

The estimates of average biomass per unit area for each species group given in the NRDAM/CME varies by type of environment (e.g., sand-mud bottom or rocky bottom) as well as seasonally (except for mollusk and lobster). In keeping with our overstated cost approach, we use the *highest* seasonal biomass estimate given in the NRDAM/CME database to characterize biomass of each species per unit area for each site. Given the biomass per unit area from the NRDAM/CME database, we can estimate total biomass for each site by multiplying the estimates of biomass by area times the total affected area for each site. The area covered by the disposal mound of sediments has been preliminarily estimated to range from 121 to 215 hectares in Narragansett Bay and covers 215 hectares in Rhode Island Sound (L. Oliver, 1999, U.S. COE, personal comm.).

As mentioned above, the NRDAM/CME uses averaged data for each species and environment type. To reflect site-specific variations in abundance among potential disposal sites, we calibrate the NRDAM/CME biomass estimate for each species to reflect available site-specific fisheries data. For this purpose, we use species-specific sampling data given in the COE EIS (1999) to develop calibration factors. In order to reflect different environments (an estuary versus an offshore sound), two calibrations are done, one for Narragansett Bay sites and one for Rhode Island Sound sites (Grigalunas, Opaluch and Luo, 2001).

Economic Data. Economic data needed include the landed price for lost commercial catch of each species and the recreational value for reduced catch by anglers. Commercial prices for each species were obtained from the most recent NMFS landings statistics for ex-vessel prices (NMFS, 2000). A weighted average was used for cases with sub-species and for “All Other Species”. In the case of mollusks (quahogs), considerable variation in the size distribution of mollusks exists between sites, and price

varies considerably by size. In this special case, we estimated a weighted price using price data from three area seafood wholesalers and converted numbers of mollusk of different sizes to biomass using growth information given in (COE 1998, 1999).

Recreational values are based on benefit transfer, using averaged values for catch by mode of fishing, taken from the open environmental and resource economics literature and summarized in the NRDAM/CME (Applied Science Associates et al, 1996). Relevant average values for the study area are \$8.54/kg for shore-based fishing and \$12.52/kg (in 1998 dollars) for coastal boat fishing. Species were assigned to appropriate modes; the All Other Species category is assigned a weighted average of constituent species.

Results for Base Case. Selected results are given in Tables IV.1 and IV.2. All monetary values in the tables are discounted present values, in constant 1998 dollars. We reemphasize that these “base case” results are overstated costs given the many conservative assumptions that were used throughout the analysis.

Key results can be summarized as follows. Incremental costs range from \$1.88 million for site 158 in Narragansett Bay to \$0.26 million for Site 16 in RI Sound (Table 1). These losses include short-term, long-term, and indirect (ecological-i.e., food web) losses for commercial and recreational fisheries. Losses for all Narragansett Bay sites (\$1.67 - \$1.88 million) are considerably higher than for RI Sound sites (\$0.26 - \$0.40 million). Given the data uncertainties involved, we cannot strongly distinguish between sites in the Bay, nor can we easily distinguish between sites within the Sound.

**TABLE IV. 1. Lost Values of Catch by Site and Species in 1998 Dollars
(thousands)**

Sites		Quahog	Lobster	Herrin g	Flounder	Tautog	All Other Species	Total
Nara- gansett Bay	3	\$8.3	\$42.7	\$0.3	\$67.9	\$854.6	\$694.7	\$1,668.5
	157	\$5.8	\$48.5	\$0.1	\$133.1	\$447.2	\$969.4	\$1,604.1
	158	\$13.0	\$58.6	\$0.2	\$155.3	\$521.7	\$1,131.0	\$1,879.9
Rhode Island Sound	16	\$4.7	\$96.2	\$17.5	\$27.1	\$23.3	\$87.4	\$256.1
	18	\$6.1	\$59.6	\$12.1	\$41.7	\$23.3	\$147.0	\$289.9
	69A	\$1.1	\$71.5	\$11.6	\$110.0	\$23.3	\$184.1	\$401.6
	69B	\$1.5	\$58.2	\$1.4	\$101.2	\$23.3	\$117.5	\$303.1

For all sites, except Bay site 3, the largest loss by category of fish is for the “All Other” classification, a category that includes many species and has the largest aggregate biomass for each site. For individual species, tautog accounts for the highest cost in Narragansett Bay (see next paragraph); flounder and lobster have the highest cost for sites in Rhode Island Sound.

Recreational losses exceed commercial losses for Bay sites and are considerable in all cases (more than 20 percent of total losses). The high recreational losses for Bay sites are

due to (1) the relatively large mortality to tautog, for which much of the Bay is a nursery area, (2) recreational use of this species is high, and (3) the marginal recreational fishing values are high as compared with marginal commercial values. The estimated high recreational losses underscore the significance of including this category of losses in economic assessments of disposal costs.

For all potential sites, long-term effects are considerable-more than two-thirds of the total cost (not shown here). This emphasizes the importance of using a cohort-type framework to capture annual losses due to mortality to different cohorts, including juveniles and young of year. Also, food web effects are non-trivial for all sites and are half as large as the short-term costs, illustrating the significance of considering food web effects in assessing disposal costs.

Sensitivity Analyses. An important issue concerns how the results given above might change if any or all of the assumptions used were altered. Sensitivity analyses examine: (1) larger size of impact area, (2) delayed habitat recovery, (3) larger food web effects, (4) use of a lower discount rate, and (5) combination of (1) - (4) (Table IV-2). Only one factor at a time is varied (all other base-case data are maintained) so that the effect of a particular change can be highlighted. The exception is the “All-Sensitivity-Conditions” case, which assesses simultaneous changes in all sensitivity factors.

Key results include: Bay sites continue to have substantially higher costs (\$2.8 million - \$3.4 million) than Rhode Island Sound sites (\$0.46 - \$0.74 million) in all sensitivity cases. The relative ordering among individual Bay sites changes slightly across sensitivity cases. Again, it is difficult to distinguish among sites within each of the two areas, given the many uncertainties involved (although sites 158 and 69A appear to have higher somewhat higher costs). For the ranges considered, increases in the size of the disposal mound and delays in recovery have the largest effect on costs. Hence, these issues may merit additional attention when evaluating in detail site disposal options.

IV. D. 1. c. Loss of Bay Bottom

Port development often involves filling in of inter-tidal and sub-tidal areas. Assuming the loss of this habitat is a limiting factor on biomass of particular fisheries, the loss of this land eliminates, in perpetuity, the natural functions or services of the area in supporting fishery production. If we know the annual value of these natural functions per acre of sub-tidal land, the value V_{SBL} of the submerged Bay lands lost due to development is

$$V_{SBL} = \sum_{t=0}^T V_{t,SBL} / (1+r)^t \quad (3)$$

Where $V_{t,SBL}$ is the annual value of filled in bay bottom land, and r is the interest rate used to discount future monetary values to arrive at a present value.

In the example given immediately above, estimates were given of the cost per acre of dredge disposal for three sites in Narragansett Bay and four in RI Sound. Elsewhere, we have estimated the value of intertidal wetlands (Opaluch, et al., 1999). It is possible to take estimates like these and convert them to a value for loss of use of Bay bottom, as is shown in our illustrative case study of port development in Chapter V.

TABLE IV. 2. Sensitivity Analyses for Total Commercial and Recreational Losses in 1998 Dollars (thousands)

Area	Site	Base Case Result	25% Increase in Size of Mound	1 Year Delay in Habitat Recovery	3% Discount Rate	100% Food Resource Export	All Sensitivity Conditions
Narragansett Bay	3	\$1,668.5	\$2,085.7	\$1,803.2	\$1,881.6	\$1,789.3	\$2,849.4
	157	\$1,604.1	\$2,005.2	\$1,814.2	\$1,789.4	\$1,759.8	\$2,901.6
	158	\$1,879.9	\$2,349.8	\$2,128.3	\$2,095.9	\$2,063.4	\$3,404.2
Rhode Island Sound	16	\$256.1	\$320.2	\$284.3	\$295.5	\$278.3	\$462.7
	18	\$289.9	\$362.4	\$326.2	\$329.6	\$317.2	\$528.1
	69A	\$401.6	\$502.0	\$454.9	\$453.8	\$440.9	\$735.1
	69B	\$303.1	\$378.9	\$341.5	\$342.6	\$331.9	\$550.7

IV. D. 2 Other Examples

The case study presented above illustrates an economic evaluation of the impacts of dredging disposal on commercial and recreational fisheries using the productivity approach for lost catch and “Benefit Transfer” for the marginal value of the lost recreational catch. This approach thus measures lost direct consumptive uses of the affected fishery resources. However, other environmental consequences of port development activity may affect the quality, and not necessarily the quantity, of resource services, such as loss of neighborhood natural amenities. Examples of such potential impacts include the loss of open space and air and noise pollution.

Different methods are needed to address different economic values caused by external costs due to port development. Below we provide two examples of quantification of other potential costs of port development using the results of two recent studies with which one of the authors of this report was involved. One approach uses revealed preferences, an indirect approach in this case using a property (“hedonic”) model to assess the losses in environmental amenities as reflected in property values. The second example uses a stated preference approach, in order to estimate people’s willingness to

pay for preservation or restoration of natural resources. Our example in this case uses the contingent choice method.

IV. D. 2. a. Example 1: Amenity Effects on Neighboring Property Values

Unless avoided through design or mitigation, port development may impose external costs on nearby residential communities. These can arise from intense lighting and noise, or development of lands in nearby communities, by that causing a loss of local amenities, such as open space. Here we consider as an example the amenity value of open space to neighboring property owners.

Open space is a public good in that no one can be excluded from enjoyment of the amenity, and use by one does not diminish use or enjoyment by others. Since there is no direct market for open space amenities as such, direct market evaluation for this type of quality change is not applicable. However, amenity affects will be reflected in neighboring property values. Thus, observable property price changes can be employed to infer the value of the environmental amenity (which is not directly observable) by the use of hedonic price function (e.g., Freeman, 1993), as we describe below.

Hedonic evaluation assumes the price of the property is a function of the attributes describing the property itself, of neighborhood characteristics, and of environmental amenities, such as air quality, water quality, scenic views, acres of nearby open spaces, wetlands, etc. Formally, the hedonic property value model assumes that any unit of X (a parcel of land) can be completely described by the vector of its component attributes. To quantify these attributes, let c_i represent specific characteristics of the structure(s) and its lot, let q_i represent environmental characteristics, and let s_i represent neighborhood characteristics, as described above. Given $x_l \in X$:

$$P_{x_l} = P_x(c_{1l}, \dots, c_{il}, \dots, c_{ln}, q_{1l}, \dots, q_{jl}, \dots, q_{lm}, s_{1l}, \dots, s_{kl}, \dots, s_{lr}) \quad (4)$$

where c_{li} is the quantity of the i th characteristic in unit x_l , q_{lj} is the level of the j th neighborhood characteristic, and s_{lk} is the level of the k th environmental characteristic.

Data on actual property transactions are used in a regression model. The dependent variable to be explained, the observed market price of the property, is hypothesized to be a function of a set of attributes. These include site attributes (e.g., size of lot; number of rooms), neighborhood attributes (e.g., location on a highway), and environmental amenities (e.g., proximity to open space).

From this statistical relation (i.e., the hedonic price function) the marginal impact of an environmental amenity (e.g., open space) on the value of property can be calculated. This marginal value can be looked upon as the individual's marginal willingness to pay for that attribute. The aggregation of this value over all the properties affected by the

change of open space gives the economic value of the open space concerned (see, e.g., Freeman, 1993; Johnston, et al., 2001)

Johnston et al. (2001) illustrate the use of economic valuation methods for assessing the value of open space. To apply the model, sales data were used for all real estate parcels sold in the Town of Southold, in Suffolk County, Long Island, during 1996. The model combines data gathered from Town of Southold property record cards, with land use and other data gathered from the computerized geographic information system (GIS) maintained by the Suffolk County Planning Department. Altogether, the data used in the analysis provide full information on 374 parcels of land with differing characteristics and selling prices. Estimates of a first-stage hedonic price function used a transcendental function specification:

$$P_i = B_0 X_i^{B_1} \exp \left[\sum_{j=2 \dots n} B_j X_{ij} \right] \quad (5)$$

Where P_i is predicted market price of the i^{th} property, x_i ($i = 1, \dots, I$) are the attributes, and the B 's are the coefficients to be estimates and represent the percent change in P for a unit change in an attribute, x .

Generally speaking, the model fits the data well. The estimated coefficients (the B 's in (1)) all had the correct sign and virtually all were highly significant statistically (i.e., there was only a small chance that the variable of interest had no effect on property price). See Johnston and Grigalunas (1999) and Johnston et al. (2001) for details.

An interesting finding was the importance of open space to neighboring property owners. Property located adjacent to open space was worth 12.83 percent more on average than other homes, allowing for the influence of other factors affecting the value of the property (Johnston and Grigalunas, 1999; Johnston *et al*, 2001).

Using such a method, the loss of open space due to port development could be translated into a loss of amenity services to nearby property owners. To assess the economic cost of loss of open space in residential areas due to port construction, a challenge would be to isolate development of open space due to the port *over and above* development of the space in the absence of a port. This is no mean feat since most areas will become more developed, over time, even in the absence of a port.

The Hedonic method also is well suited for examining the effect of noise or other externalities from port development where the external effect occur over space and can be observed through the property market. With such results, one could include the estimate of the associated external cost in an overall social benefit-cost analysis of the proposed project (Chapter V); the results also could be used to compare the costs and benefits from noise suppression mitigation actions (e.g., fences, berms, equipment design) or with mitigation actions, such as purchase of open space elsewhere.

IV.D. 2. b. Example 2: Public Goods Effects of Natural Resource Amenities.

The property value model (hedonic price function) given in the section immediately above provides estimates the use value of amenity changes through their impacts on neighboring (i.e., local) property values. However, missing from the property model is any public good value that the public at large might have for the target environmental resources. For example, the general public, beyond those residing in the immediate neighborhood, may also value area amenities, such as open space, wetlands, and farmlands, even if they live some distance away from the area affected by the loss of environmental amenities. Excluding this non-use value, therefore, will underestimate the total value of losses due to reduction in broader area public good amenities.

Port-related development that causes a net loss of open space, wetlands, or other amenities could impose losses on the community at large, unless avoided by design measures or compensated for by mitigation. A recent study using a contingent choice framework (Mazzotta, Opaluch, and Grigalunas, 2001) examined public preferences for natural resource amenities for the Peconic Estuary in NY.

The contingent choice survey asked respondents, in a carefully developed questionnaire, to choose between two programs. Each program concerned preservation and restoration of specific resources, including open space and wetlands, for a specified cost per year for each household. “No New Action” also was an option given to respondents. One example question from the study is given below to illustrate the methodology used. In the actual study, each respondent was asked a set of five such questions, each differing with respect to the quantity of resources provided by a program and the annual costs of the program to each household.

Useable responses were obtained from 968 residents and second homeowners (the area studied is a major summer vacation destination) who completed the survey. Of these, 897 (92.7%) answered at least one of the five contingent choice questions; and of the 4,840 total possible choice questions, 4,307 (89%) were answered.







The study found that residents and second homeowners have a strong preference for preservation and restoration of open space, wetlands, agricultural farms, eelgrass (a productive habitat for fish and shell fish) and other natural resources, and households indicated their willing to pay for such programs. Although the relative ranking of resources was more robust than the estimates of dollar values in this case, the suggestive results from the best model (the nested logit model) shows that the public had the highest marginal value for farmland (\$74,562/acre), followed by eelgrass (\$69,962/acre), wetlands (\$56,669/acre), shell fishing areas (\$31,742/acre) and undeveloped land (\$14,024/acre).

Figure IV-3. - Instructions and Example of Contingent Choice

4. If you had to choose one of the 3 options below, which would you choose?

Circle Program A, Program B, or No New Action below.
(Do not compare these to programs on any other page.)

Projected Results for

	No New Action	Program A	Program B
<ul style="list-style-type: none"> To preserve what we have, new actions needed. Since it is very expensive to fix all problems, difficult choices must be The next few questions show how actions will change conditions in The following programs are We are trying to learn which resources are important to you and how much you would to protect Consider each question separately. Do not them 	 25% of wetlands will be lost or degraded about 12,000 unharmed acres will  Unpolluted shellfishing areas small bays will decrease by 5%, to about 25,000 \$0 per year No new cost to each East End household.	 Current wetlands will be preserved at 16,000  Unpolluted shellfishing areas small bays will increase by 10%, to about 29,000 \$300 per year Cost to each East End \$300 per	 Wetlands will increase by 10%, to about 17,500  Unpolluted shellfishing areas small bays will increase by 5%, to about 25,000 \$100 per year Cost to each East End \$100 per

Summing up the two examples given above, we should note that the first example valuation method is based on the change of property value due to variations in environmental amenities, and hence only reflects amenity losses to *adjoining* property owners. In contrast, the second example provides estimates the broader (“existence”) value that the *public at large* has for preservation and restoration of area environmental resources. Therefore, the two examples present estimates of different values the public holds for the same environmental resources.

Note also that there is a possibility of some double counting of losses, if the willingness to pay by individuals in the contingent choice study also includes the value they hold for neighboring amenities. In such a case, adding the estimate of nearby property value changes due to alteration of open space to the value estimated using contingent choice would count the neighborhood value twice. Thus, the two approaches might best be viewed as establishing bounds for the amenity losses of a change in a resource with the lower bound given by the hedonic results and the upper bound by the contingent choice result.

IV. D. 2 c. Other Potential External Effects

IV. D. 2. c. i. Peak Hour Traffic Congestion

Congestion is another issue of concern in many port areas, although typically congestion is due to traffic from *many* sources of which traffic from the port may be only a small part. Nevertheless, local congestion can be an issue, as was found upon completion of

America President Line's Terminal 5 in Seattle's Southwest Harbor, for example, where trucks using the port created local congestion until an overpass was constructed to bypass the local public road.

More generally, congestion arises when individual vehicles entering traffic impose costs on others, typically those in the queue behind them. Drivers have an incentive to consider the value of their time and gasoline consumption, which are the private costs they bear, but not the costs they impose on other drivers behind them. The congestion problem is common at canal locks, airports, tollbooths, and other locations where peak use exceeds capacity.

Figure IV-2 shows a simplified example of a road that experiences congestion at peak use. The marginal private costs per trip for the road (time, fuel, wear and tear on vehicle) are assumed to be a constant. DD shows the level of demand for trips in a base period (or an off-peak period). For this road, traffic per period up to T^* causes no external costs. After T^* , however, crowding sets in and the private costs are less than the social costs (private costs *plus* external costs--i.e. the cost imposed on those in vehicles behind in terms of lost time and fuel). As traffic increases, the social costs can get very high as is illustrated at T^{**} .

The costs of congestion can be substantial (as anyone who has been stuck in beach traffic on a hot summer day knows). This external cost is the value of a person's time multiplied by the time in traffic, plus the extra fuel used during the delay. For example, suppose heavy traffic delays the average driver's arrival at their destination by an hour. Assume further that the value of the driver's time is, say, \$15 per hour on average, 2000 vehicles are delayed, there are 1.5 people per vehicle, and the extra gasoline used is 2 gallons @ \$1.50 per gallon. In this simplest of cases, the cost for this one-hour delay would be \$135,000 ($2000 \times 15 \times 1.5 \times 2 \times 1.50$). Multiplied over many days, and discounted, the present value of congestion costs could be a very sizable figure.

Of course, road and interchange improvements, better use of signage and radio announcements, and other demand management measures can reduce congestion. Such measures will be worthwhile if they cost less than the present value of area as shown in the Figure.

It is reemphasized that trucks servicing container ports are usually only a contributor to traffic congestion, and the farther one travels from the port, the smaller the problem caused by the port. The challenge, therefore, is to estimate the increment to social cost due to the port. This requires estimates of traffic with and without the port at both peak and off-peak periods. And there is an important probabilistic dimension to the problem since arrivals by vehicles at bottlenecks and occurrence of accidents (another important source of delays and also a function of traffic) are chance events, not deterministic.

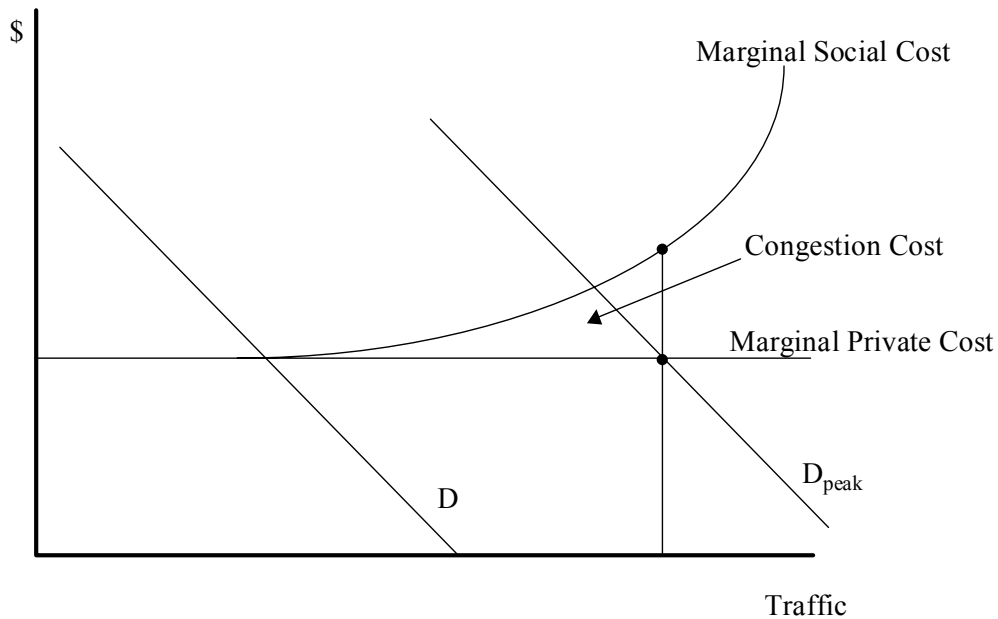


Figure IV-2. Simplified Depiction of Road Congestion Cost

IV. D. 2.c.ii Traffic flow interruptions at railroad crossings

Use of trains with double stack capability as part of an efficient intermodal system is a requirement for a successful large port. Trains have the advantage of being cheaper than trucks beyond some distance (several hundred miles), and they can reduce road traffic around the port, and hence reduce air emissions and wear and tear on roads from this source.

Trains can cause problems, however, for communities at road crossings. Delays are caused when long trains cars double stacked with containers slow traffic and delay emergency vehicles, for example. In the State of Washington, for instance, the Seattle Port Authority has had to find funding to construct overpasses and underpasses at rail crossings throughout the state at a cost of \$356 million (Washington, 1999).

IV. D.2 c. iii. Introduction of non-native species

The potential for container (and other) ships introducing non-indigenous species into harbors and estuaries has become an important concern (e.g., Carlton et al., 1995; Smith, et al., 1996). Species are typically transported in ballast water. This issue was not studied during the first year of our study, and hence we simply point out this potential issue and restrict ourselves to a brief statement of concerns and issues.

Key issues include (1) whether a vessel carries an invasive species, (2) whether the species carried will survive (the longer the trip, the lower the chance an organism will

survive), (3) if species discharged into coastal waters will survive, and (4) if so, propagate, which is not guaranteed. Finally, a fundamental issue concerns (5) whether species that propagate cause harmful effects (or conceivably, beneficial effects) and (6) the magnitude of these effects.

Measures apparently are available to control potential introduction of non-indigenous species, through exchanging ballast at sea, or through use of oxygen deprivation, chemical biocides, thermal treatment, and other approaches (e.g., Carlton et al, 1995). However, compliance, the costs involved, and who would pay the costs of implementation, including monitoring, are issues.

IV. D. 2 c. iv. Air Pollution

Considerable truck, vessel, and train traffic may accompany port development. Air emissions from these sources are a potential environmental issue, and the effects to be considered, as always, are net effects: the increase in emissions over and above what would occur without a port.

The importance of net emissions in a particular case will depend upon (among other factors) the type and amount of pollutants and the issue they pose (e.g., particulates and ozone), which in turn depends upon the source of energy for terminal equipment (electricity versus diesel), the relative roles of trucks versus train to move containers, and the number of moves through the port. Rather than emissions per se, it is the net changes in exposure of people that is significant in assessing environmental costs. Air pollution issues will be examined in future phases of this project.

IV. D. 2. d. Example 4: Environmental Mitigation

Port development necessarily alters the shoreline and may cause loss of intertidal wetlands (salt marsh), submerged eelgrass, or subtidal bottom. In some cases migration routes for spawning species might be impaired (an issue for fisheries in Tacoma and Vancouver). Loss of the natural services (or functions) of these natural assets would continue indefinitely, unless mitigation takes place. For example, an option might be to restore or create wetlands, or create habitat for fish or wildlife. Important questions become:

- *what* is to be restored--the resource itself or resource services--and
- *how much* mitigation is to be done, i.e., the scaling issue;
- what alternative provides the *cost-effective* restoration option?, and
- do the *benefits* to be obtained from the restoration justify the costs?

The type of restoration action--the answer to the “what?” question--will depend upon the environmental harm that is to be mitigated. For example, if port development impacts a particular fishery, then a mitigation action that provides additional habitat may be

appropriate. This was done at the DELTA port just outside of Vancouver, British Columbia, for example, where fish habitat was created at the dock site. Or, if port development causes loss of a resource, such as wetlands, then comparable wetlands may be restored or protected as a mitigation measure, as is done to make up for loss of coastal land due to port development in Long Beach, California. In still other cases, efforts have been made to create access to the shoreline for coastal recreational users who were excluded by construction or expansion of a port, as occurred in Washington State.

Once the “What?” question is resolved, the scaling issue can be addressed. This involves the estimation of the *amount* of restoration required to compensate for the loss resource or service. For example, if lost services from destruction of a wetland, or loss of use of a shoreline, could be restored instantaneously, the restoration of the lost resource to baseline would be enough.

On the other hand, restoration may not be completed for some years. In such cases, there is a loss of *interim* services. The units of services involved in the case of wetlands, for example, are *acre years of services*. Hence this is an application of the habitat equivalency approach, in which all wetland acres are assumed to provide the same services, by that avoiding the need to estimate the value of each acre of wetland or other resource lost and restored.

To make up for the lost interim services, restoration beyond the baseline level may be required (“compensatory” restoration). The basic logic is to restore beyond baseline an amount that just offsets the lost interim services, taking into account the capitalized value of interim lost services and the discounted value of future services due to the restoration.

To estimate the amount of restoration required, one solves for W_m in the following expression:

$$\sum_{t=t_L}^m W_L(t)(1+r)^{-t} = \sum_m W_m(t)(1+r)^{-t} \quad (6)$$

where W_L is acres of wetland lost at time t_L , W_m is the number of acres of wetland created for mitigation at time t_m , and r is the discount rate. The appropriate discount rate is the real, risk-free social discount rate. As an approximation, the real, long-term rate on federal government bonds is often used as a proxy for the “true” social discount rate. Or a rate may be administratively determined. For example, NOAA uses a 3 % discount rate in natural resource damage assessment cases.

To address the cost-effectiveness issue, different approaches for mitigation must be considered, and the one with the least-cost will be selected. This is not a trivial calculation in most cases because of the many factors to be considered. For example, two alternatives for restoring a resource may have different costs over time and may also have

different results in terms of the resource restored. In such a case, a simple comparison between the costs is inadequate, as is a simple calculation of cost per unit, which would divide the number of resource units restored into the discounted costs -- what number is to be placed in the denominator?

The appropriate calculation is to divide discounted costs by discounted resource units. This recognizes that both costs and resources vary over time.

IV. E. Summary and Conclusions

Port development raises many environmental issues, real and perceived, that are important for public policy in port development. Failure to address environmental issues early in the process can cause delays, design changes and raise costs, by that affecting the financial feasibility of proposed port development. However, weighing the significance of these issues and designing avoidance or mitigation measures is difficult because (1) difficulties with quantification and the many sources of uncertainty and (2) external effects occur outside of markets and hence require the use of non-market valuation methods.

Estimates of the magnitude of potential port-related external costs can contribute to public debate in several ways. Such results put environmental costs in perspective, expand opportunities for benefit-cost analyses, can contribute to site selection for sediment disposal (as in the case study presented in this paper), and also can help in selecting the type and scale of any design or mitigation actions for addressing several potential environmental issues. Several generic environmental issues commonly mentioned in connection with port development were noted, and examples were used to illustrate how different types of potential costs could be quantified. These and other issues will be examined more fully in forthcoming work.

Finally, we note that for the results of valuation studies (and other technical studies) to be most effective, they must of course be objective and credible. Beyond that, they must be presented in ways that engage the attention of agencies and stakeholders. In this regard, an important part of our ongoing project involves development of a decision support system, a new Policy Simulation Laboratory at the University of Rhode Island in later years as our work is final stages. For example, the ability to visually examine issues within a Geographical Information System, or a virtual reality system, can improve understanding of the location and scale of issues and of options for mitigation. Such an approach also lends itself to carrying out a series of “what if” analyses to investigate the nature and scale of potential consequences of different levels of activity, different types of development, or alternative regulations.

V. SOCIAL BENEFIT-COST ANALYSIS: FRAMEWORK AND EXAMPLES

V.A . INTRODUCTION

This chapter describes the framework that eventually can be used to assess the benefits and costs (“social profitability”) from container port development. Standard principles of benefit-cost analysis, environmental economics, and welfare economics are drawn upon for this purpose (e.g., *Principles and Standards*; Freeman, 1993; Kopp and Smith, 1993; Grigalunas and Congar, 1995).

First, we define social benefit-cost analysis and explain how it can be used to assess port development issues. In order to make the discussion concrete, we provide selected, illustrative applications of the concepts involved using readily available information for our case study, Quonset Point.

We do not undertake a full benefit-cost analysis but instead focus on explaining and illustrating the framework developed in Year One of our project. Ongoing analysis for Years 2 and 3 of this project will substantially refine and expand the information available for later benefit-cost estimates.

V.B. CONCEPTS

V.B.1. Social Benefit-Cost Analysis

Social benefit-cost analysis has as its goal an assessment of the net economic benefits (benefits less the costs of realizing the benefits) of proposed policies or programs to a defined group, usually the nation as a whole. For example, the US Army Corps of Engineers (USCOE) typically assesses the benefits and costs to the nation as a whole when evaluating potential port projects, although the USCOE analyses only recently has begun to quantify environmental costs and benefits as proposed in this report.

Social benefit-cost analyses should identify and quantify, to the extent possible, all important market- and non-market valued effects. Hence, the scope of a social benefit-cost analysis is far broader, and much more inclusive, than the financial feasibility analysis for a port developer presented in Chapter III. It also is much more difficult since many important benefits and costs are not fully captured – if reflected at all -- in markets, and considerable detective work is required to uncover the value the public holds for these non-market or “extra-market” goods and services (see, e.g., Braden and Koldstadt, 1991; Freeman, 1993; Kopp and Smith, 1993; Grigalunas and Congar, 1995). Notwithstanding these difficulties, we argue that even imperfect information can contribute to better informing public policy discussions of port development, and we illustrate this by providing some examples later in this Chapter.

Done carefully and objectively, benefit-cost analysis can provide valuable and otherwise unavailable information to contribute to collective decision making for container port development. As described in Chapter I, and elaborated upon below, important features

of benefit-cost analysis are that (1) it compels the researcher and policy maker to identify clearly the benefits and costs involved, and (2) it recognizes that the labor and other resources used for any project are drawn away from (i.e., come at the cost of) other valued uses of the resources.

Benefit-cost analysis is not a mechanical exercise, and requires reasoned judgments by the researcher. In the sections that follow, we attempt to set out clearly the concepts, assumptions, and judgments used so that readers can appreciate the potential usefulness of benefit-cost analysis, as well as the limitations and very preliminary nature of our results to date.

We follow standard practice and focus on the *incremental* effects of a project, or the outcome *with* a project as compared to what would happen *without* the project (sometimes called the “baseline”). This perspective recognizes that the land, labor, subtidal coastal areas, and other resources that would be dedicated to a port have alternative uses. These alternative uses would provide benefits; hence, their use to support a port comes at a cost -- an opportunity cost. At the same time, alternative uses of lands for non-port uses will also generate traffic, air emissions, diminish open space, and impose other environmental costs. The effects of a port, therefore, should be measured as the consequences of the port over and above what would happen without the port (the baseline).

V.B.2. Accounting Stance or: Whose Benefits and Costs Count?

The social benefits and costs of a project may be assessed from several different and legitimate points of view, depending upon the purpose of the study. In keeping with the overall objectives of our framework, our interest in this Chapter is concerns the assessment of benefits and costs of container port development from the viewpoint of: (1) the nation as a whole, and (2) a state or region¹.

National benefits and costs measure the net economic contribution that port development makes to the country’s goal of an efficient national transportation network. Benefits and costs at this level are measured to whomever they accrue. An important implication of this national perspective is that transfers (e.g., taxes) or purely distributional effects between areas and groups (relocation of activity, labor, or other resources from one area to another) can be ignored since they are a wash from the point of view of the nation as a whole.

State benefits and costs, on the other hand, are measured from the perspective of *current residents of a state*. The rationale for using existing residents as the affected population is that (1) container port development decisions are largely implemented at the state (or sometimes, regional) level, and (2) it is the current residents and public officials who will

¹ For example, for trans-national issues, such as a linked inter-country transportation network, cross boundary pollution, or global warming, an international or even a global benefit-cost accounting stance would be appropriate.

influence decisions concerning whether or not, and under what conditions, a port would be developed, including decisions concerning possible financing and subsidies.

This “accounting stance” has important ramifications for our assessment of benefits and costs for proposed ports, as we explain and illustrate below. For one thing, it requires that the *distribution* of benefits and costs be assessed.

V. B. 3. Elements of Social Cost-Benefit Analysis for Container Port Development

V. B. 3. a. National Viewpoint

Net benefits at the national level, NPV^N are made up of several elements. These include transportation cost savings due to the project, less the costs of the resources for planning, investment, operation, and maintenance. Net gains to workers (payments over the value of their time in its next-best use), net environmental costs, and mitigation also must be considered. The needed calculation is as follows:

$$NPV^N = \sum_{t=t_0}^T [TCS_t^N - I_t^N - C_t^N - (EC_t^N - EB_t^N) - MIT_t^N + NGW_t^N] / (1+r)^{t-t_0}$$

where

NPV^N = Net present value to the nation

TCS_t = Transportation cost savings at time t with the port, i.e., the cost of delivering goods with the port, less transportation cost without that port

I_t^N = Incremental investment costs in time t for planning and implementing dredging, port infrastructure, superstructure, roads, rail facilities and offsite investment (e.g., for road connectors, overpasses, and rail crossing).

C_t^N = Operating and maintenance costs of port in time t measured by opportunity cost of the resources used

EC_t^N = Environmental costs of project at time t, *after* mitigation

EB_t^N = Environmental benefit of project at time t, after mitigation

MIT_t^N = Mitigation costs in time t

NGW_t^N = Net gains to workers--payments port workers receive in excess of the value of their time in its next-best use (i.e., opportunity costs).

r = the social rate of discount (in practice, the inflation-adjusted rate on long-term federal bonds)

t_0, T = Respectively, the initial and last period considered in the study

Taxes and fees are not included, as noted, because these items are transfers between groups and neither costs nor benefits from a national viewpoint. Also ignored is the movement of economic activity into a state due to port development (“location effects”). The reason for this is that migration into an area comes at a cost (lost output) to the source areas, so that overall there is no net gain to the nation (e.g., Howe, 1986).

Environmental costs and possible benefits are measured after mitigation, taking into account the costs of mitigation. Including the net gains to workers recognizes that workers may be paid more than the value of their time in its next-best use (see discussion in text, below).

V. B. 3. b. State Residents' Viewpoint

Our focus on benefits and costs to current state residents, NPV^{SR} , is motivated by the important role individual states play in US port policy and the resulting need for information that might contribute to such decisions. From the viewpoint of current state residents, the economic consequences of a port has several elements:

$$NPV^{SR} = \sum_{t=0}^T \{ [TCS_t^{SR} + NGW_t^{SR} - C_t^{SR} + (EB_t^{SR} + NFE_t^{SR}) - (ONIC_t^{SR} - ONIB_t^{SR}) - (OFIC_t^{SR} - OFIB_t^{SR}) - MIT_t^{SR} - O_t^{SR}] \} / (1+r)^{t-t_0}$$

where:

TCS_t^{SR} = Transportation cost savings to *resident* households and businesses on goods moved through the port, as compared to the next-best transportation alternative

NGW_t^{SR} = Net gains to resident workers--payments port workers receive in excess of the value of their time in its next-best use (i.e., opportunity costs).

C_t^{SR} = Operating costs paid for by state

EC_t^{SR} = Environmental costs to state residents, after mitigation.

EB_t^{SR} = Environmental benefits to state residents, after mitigation

NFE_t^{SR} = Net fiscal effects: transfers from, or fees levied on, *outside* parties, less the costs of administering the port

$ONIC_t^{SR} - ONIB_t^{SR}$ = Respectively, onsite investment costs and benefits paid by the state

$OFIC_t^{SR} - OFIB_t^{SR}$ = Respectively, off-site infrastructure investment and operating costs incurred by the state due to the port (e.g. construction and maintenance of a road connector or overpass), less the benefits residents receive from use of these facilities (e.g., time saved by use of the connector or overpass)

MIT_t^{SR} = Mitigation costs paid by state at time t

O_t^{SR} = Other costs (e.g., special studies or permits) paid by state

r = the discount rate

The focus on current residents of a state weighing a container port proposal has important implications for what is counted as a benefit or cost, as noted. Excluded, for example, are transportation cost savings that residents of *other* states receive from a port. In fact, many ports largely serve out-of-state markets (e.g., the Ports of Charleston, Seattle, and Halifax). The aggregate national transportation savings from the ports concerned can be large, even though much of it accrues to residents of distant markets. On the other hand, we count as a gain fees on container moves through a port collected from outside parties

-- less the administrative costs incurred to realize these fees -- since the fees received comes at the expense of “outsiders”.

V. C. EXPLANATION OF CONCEPTS USED

V.C.1 Transportation Cost Savings

At the national level, transportation cost savings are measured as the change in Consumer Surplus for users of containerized goods. This is illustrated in Figure V-1, which shows (1) the hypothetical annual demand function for container services through a new port, D_oD_o , and (2) the associated costs, which for simplicity we show as perfectly flat (i.e., constant costs). In Figure V-1, consumer surplus is measured as the shaded area under the demand curve between the prices with and without the port, P_w and P_{wo} , projected over time and then discounted.

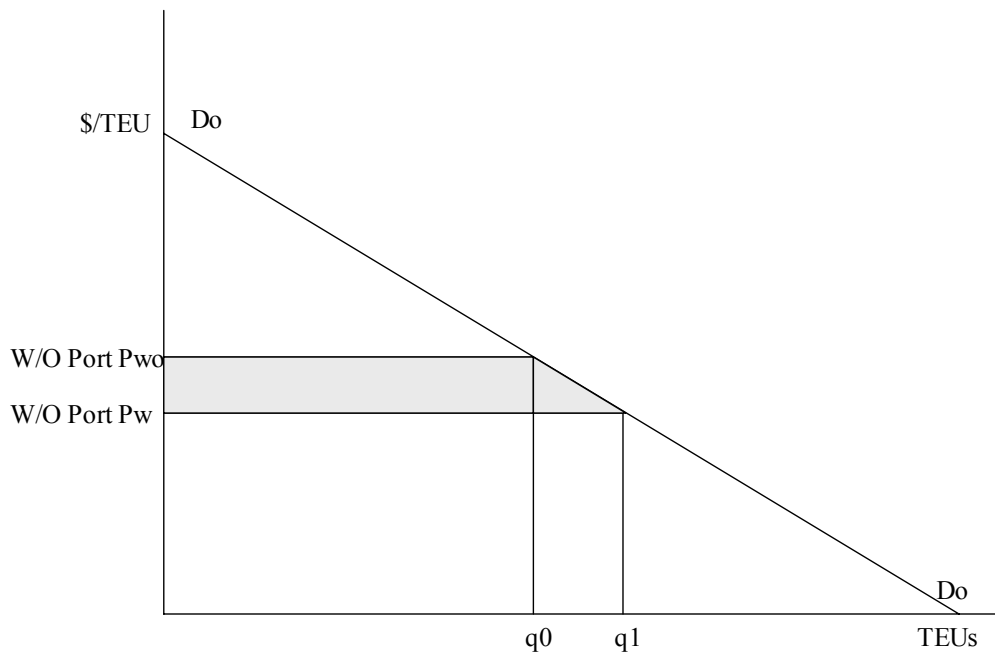
The demand function D_oD_o slopes downward since changes in the terminal fees per box will change the number of boxes moving through the port (the “Law of Demand”). The greater the competition with other ports, the flatter (more elastic) will be D_oD_o , reflecting the fact that the port will have less market control over the fee it can charge. An obviously important – but very difficult -- issue is the location and slope of D_oD_o for a new port (see Chapter II).

For state residents, transportation cost savings result from a port when (1) resident-owned businesses earn higher profits, and (2) residents pay less for goods. Transportation cost savings for current residents will be only a share of total transportation cost savings illustrated in Figure V-1, and the share will depend upon the extent of the local market for containerized goods. For example, ports in Long Beach/Los Angeles and New York/New Jersey serve enormous local markets and hence provide a substantial transportation cost saving for residents of Southern California and New York-New Jersey, respectively. On the other hand, the share of transportation cost savings accruing to state residents likely is relatively small for ports like Norfolk, Charleston, Seattle, and Halifax. All of these ports transship a large share of containerized goods by rail outside the state, especially to and from the mid-west and, for large West Coast ports, on to the East Coast (via the Mini Land Bridge). Of course, even a small share of a very big number can be substantial. An example given later suggests that transportation cost savings to state residents can be far from trivial, even if the share accruing locally is relatively small.

V. C. 2. Net Gains to Workers.

The wages paid to carry out a project are a cost to be subtracted from benefits to measure net social benefits. This is because the use of workers in any activity necessarily draws them away from (i.e., comes at the cost of) other valuable uses of their time, such as other employment, work at home, or leisure activities. As we point out below, with full employment and mobile resources, the price paid for use of a resource is a good measure of the cost to society of using the resources concerned--labor in this case.

Figure V-1: Hypothetical Demand for TEUs With (w) and Without (wo) the Port



However, when the workers hired would otherwise be involuntarily unemployed, the wages paid overstate the true cost (opportunity cost) of the labor used.² Under conditions of unemployment, therefore, it is appropriate to adjust the observed market price of labor downward to reflect better the true opportunity cost of workers' time. The downward adjustment in effect increases the net benefits of the project, and hence makes a project more economically attractive. We refer to the results of this adjustment as showing the *net gain to workers* inasmuch as the gain is captured by workers.

Here we present concepts and a methodology to measure this net gain to workers. The analysis of benefits in public projects is an important, and all-too-often confused issue. Hence, we explain the concepts involved, and our approach, in some detail. Two cases are considered in sequence, one where there is full employment in the area and second where unemployment exists.

V. C. 2. a. Full Employment Case

With full employment and mobile resources, companies seeking to hire workers by definition must attract them from other activities. To attract them, companies must pay the workers an amount similar to (perhaps slightly more than) the value of the worker's

² The same arguments apply to capital equipment and other inputs, but labor costs are usually the main component of value added and much confusion surrounds popular discussions about how these costs should be considered when studying the "impacts" of a new project. Further, the services of capital are "storable", while labor is not (unused labor services are lost forever). For these reasons we focus on labor costs.

time in its next best use. Given full employment, workers who fill new in-state positions can be drawn from three sources: (1) other businesses, (2) commuters who work out of state, and (3) new residents, or individuals who would commute to jobs in the state.

The amount a worker is paid reflects the contribution that the additional labor is expected to make to profits. Companies hire workers when what they contribute to profits equals or exceeds what they are paid. If new workers are diverted from other businesses, Case (1), then the businesses losing labor have fewer workers, pay lower total wages, and have a reduction in the value of the output they produce. The reduction in output at the original place of employment is roughly equivalent to the wage paid to the worker and the added output at the new job. Hence, there is a negligible *net* gain in this case.

If new jobs are filled by residents who had been commuting out of state to work, Case (2), then a gain to residents will be realized. It is measured by the sum of (1) the excess the worker is paid in his/her new in-state job over the former job, (2) any savings in commuting costs, and (3) out-of-state taxes formerly paid that now accrue to the state hosting the port.

On the other hand, if new residents or inbound commuters are attracted to fill the new jobs (Case (3)), then by definition there is no gain in wage payments to *current* residents. Following our accounting stance, there is no benefit to the state (although tax collections on these individuals, net of the cost of public services the new workers demand, are a gain).

By now the logic and the argument should be clear. To summarize, with *full employment and mobile resources*, only a modest share of the wages paid by a new industry represents an overall gain in the income to state workers because there is an opportunity cost for workers' time³. These consequences are not readily apparent because the jobs and wage payments at the new activity are concentrated and highly visible while the *reduction* in workers, wages, and output at other businesses losing workers is much more diffuse. Still, the net gain to workers in the aggregate could be non-trivial, even though only a *share* of income is a gain, as we show below.

Given the above reasoning, it follows that when there is full employment and mobile resources, indirect or induced ("multiplier effects") on income in a state will be smaller than commonly thought in many public discussions. The reasons for this are that (1) only a share of a new industry's purchases will be local (so called "indirect effects"), (2) the payment to labor due to indirect purchases is only a small share of the expenditure (almost always less than 50 %), and (3) the labor used in these businesses is paid only slightly more than their opportunity costs. As a result of all of these factors, the fraction of payments to workers that represents a net gain from so called multiplier effects tends to be small—and with full employment, quite small.

³ An increase in demand for labor large enough to raise wages would increase the labor force and wage payments -- but also would increase business costs ("pecuniary externalities"), by that reducing profits for firms in competitive industries who cannot increase their price. Given a large workforce in most states, a very substantial increase in demand likely would be needed to drive up wages.

Induced effects (gains in local businesses due to additional area spending by workers in the new industry) also will tend to be small. This is because (1) the increment to income in new jobs is small for reasons given above, (2) only part of this increment is spent on goods made within the state, and (3) only part of the payments for inputs go to labor—and (4) labor is roughly paid its opportunity cost.

A numerical example illustrates the importance of the above arguments. Suppose a new port hires additional labor for \$1,000. Suppose further that the value the workers attach to alternative uses of their time is 90 % of the wage, so that 10 % of the wage is a net gain to the worker. Then, the net monetary gain to the worker is \$100 ($=\$1,000 \times 0.10$) — as compared to the total wage payment of \$1,000.

Now, assume (generously) that the worker spends the *entire* extra \$100 within the state, that the industry in which the \$100 of purchases is made pays its workers an additional \$50 (a likely overstatement), and that these workers also place a value on their time equal to 90 % of the wage. Then, the increase in income due to this “indirect effect” is \$5.00 ($=\$100 \times 0.5 \times 0.10$) and the total “direct *and* indirect” net gain to workers from a \$1,000 wage payment at a new activity (port) is \$105.00.

The “responding effects” could be carried through an infinite number of rounds, but after only one or possibly two rounds, the net increase in income to workers through responding effects is quite small — likely negligible — and efforts to track down such small effects might better be devoted to other issues. (The third-round effect from the initial \$1,000 wage payment, keeping the same assumptions as in the paragraph immediately above, is \$ 0.25 ($=\$5.00 \times 0.5 \times 0.10$). In sum, one should be cautious about relying on use of purported “multiplier effects” in assessing the economic benefit of projects at the state or regional level.

A potential source of large effects—“impacts”—arises if large numbers of workers move to the immediate area to work at the port. However, these effects (“location effects”) are not a net benefit to current state residents, as they are either in-migrants from other states or come from other areas within the state. Nevertheless, an influx of local commerce and residents can be a very important issue for local communities to anticipate in order to plan for potential public service costs and the need for local revenues to cover these costs.

Unemployment case. Although the US had essentially full employment in 1999 and 2000 (some unemployment is inevitable), unemployment is all too common. The jobless rate, in fact was considerable in the early 1990s, peaking at in Rhode Island, for example, at 9 percent in 1992. Here, we explain the estimation of gains to workers when involuntary unemployment of labor exists.

When unemployment prevails, by definition the wage rate exceeds the value of a worker’s time: employees would like to work more at the prevailing wages, but demand for their services is insufficient. Therefore, a worker paid the market wage to work additional hours does realize a gain, measured as the *difference* between the market wage

they receive and the lower value that workers assign to their time at the margin. This difference can be viewed as a gain to labor due to a project⁴.

These ideas are illustrated in Figure V-2, which shows a simplified representation of the labor market for an area for a given period. The demand for labor, $D_L D_L$ reflects how much labor (in hours) businesses would hire at different wages during the period. The supply of labor, on the other and, indicates the size of the work force and the willingness of people to work (in hours) at different wages.

The demand for labor, $D_L D_L$, slopes downward to the right showing that companies will use less labor at higher wage rates and more at lower wages. The supply function $S_L S_L$ has a positive slope reflecting the fact that a higher wage must be paid to encourage more labor. For example, people will not find it worthwhile to work at a very low wage, and often a higher wage must be paid to entice people to work more hours, especially overtime, weekends, and holidays. Unemployment is evident at the assumed prevailing wage⁵, W_1 , since workers are willing to supply more labor (L_2) than businesses want to hire (L_1) at that wage, leading to unemployment shown by $L_2 - L_1$.

Suppose there is a “small” increase in the demand for terminal and yard workers and administrative personnel due to a port development (and even a thousand or more workers is not large relative to the total labor market – which is over 500,000 in Rhode Island, for example). The employer pays the prevailing wage W_1 , but the opportunity cost of the increment of labor used is W_2 , which is the minimum amount workers require (the opportunity cost or “shadow price” of time) in order to supply that additional amount of labor. Hence, the gain to workers from supplying an increment of labor at L_1 in this case is $(W_1 - W_2)$.

If we had an estimate of the opportunity cost, W_2 , we could adjust the money wage payments at a proposed port to reflect opportunity costs and then measure the incremental gain to workers, $(W_1 - W_2)$.⁶ The adjustment factor in percentage terms would be $[(W_1 - W_2)/W_1]$, and the larger the adjustment factor, the larger the share of wages that is a gain to workers.

How large is the adjustment factor, $[(W_1 - W_2)/W_1]$? Its size depends upon several factors, notably the unemployment rate. Generally speaking, the higher the rate of unemployment, the larger the adjustment to be made to calculate the gain to labor from a new development⁷. With full employment, the adjustment is quite small, as described

⁴ For similar arguments, see MIT Offshore Oil Task group (1972).

⁵ For example, W_1 might be a union wage, or the wage paid before unemployment arose but that is maintained by the employer to avoid harming worker morale by a wage cut.

⁶ Of course we want to measure the *area* $\Delta L * \Delta(W_1 - W_2)$, a very small area not reflected in the simplified figure.

⁷ In an earlier study, Haveman and Krutilla (1969) adjusted the results of prior benefit-cost (B-C) studies to examine how the outcome of the analyses might have changed, had the use of unemployed resources been considered in the original studies. They found that consideration of unemployment did warrant a reduction in the cost of the resources used and in some cases, was sufficient to allow some projects which had failed

above, but with high unemployment rates (as in 1990-1992) the adjustment would be larger and could be important.

Note that the same type of adjustment to wages used for direct workers applies for “indirect” or “induced” port development effects, but is likely to be small as these are second-order effects, as our numerical example, above shows. For indirect effects, only a small share of purchases will be made in the state, and of these purchases, only a part (usually less than 50 %) goes to workers, and only a fraction of this amount will be a net gain, as noted earlier. The same type of argument applies for induced effects.

Of course, it is hard to be confident, today, about what the adjustment to wages should be for each year of operation for a long-term project that would not even begin for several years. For guidance, we must look to the past and present--and must, in any event, adopt a pragmatic stance.

We presume that (1) those who take a new job, even with full employment, experience at least a small gain to encourage them to switch, and (2) those who are hired when there is much unemployment have a relatively large gain. As the lower bound for $[(W_1 - W_2)/W_1]$, we use 5 %; for the upper bound we use the highest value (31 %) given in a summary of prior studies in Hamilton, et al. (1991).

For example, a newly hired port worker paid, say, \$30,000, would have an adjusted opportunity cost of \$28,500 at near full employment and an opportunity cost of \$20,700 if substantial unemployment exists. Therefore, the net gain to workers would be \$1,500 at full employment, and \$9,300 with substantial unemployment. This begs the question, of course, about how to decide what the unemployment rate will be each year in the future, a subject we take up next.

To sum up, *part* of the wages paid at a new port development can be considered a gain to current residents. The gain is the difference between the wage received and the value of workers’ time in other activities, such as compensated employment, work at home, voluntary leisure. The larger the unemployment rate, the larger the share of the additional market wages that can be considered a gain to workers. However, overall the gain will be a small part of the wage received, once the opportunity costs of a worker’s time is recognized—and likely never over a third or so (31% under our assumptions)⁸. The gain to workers from indirect and induced effects will be smaller still, for the reasons given earlier.

V. C. 3. Net Environmental Effects

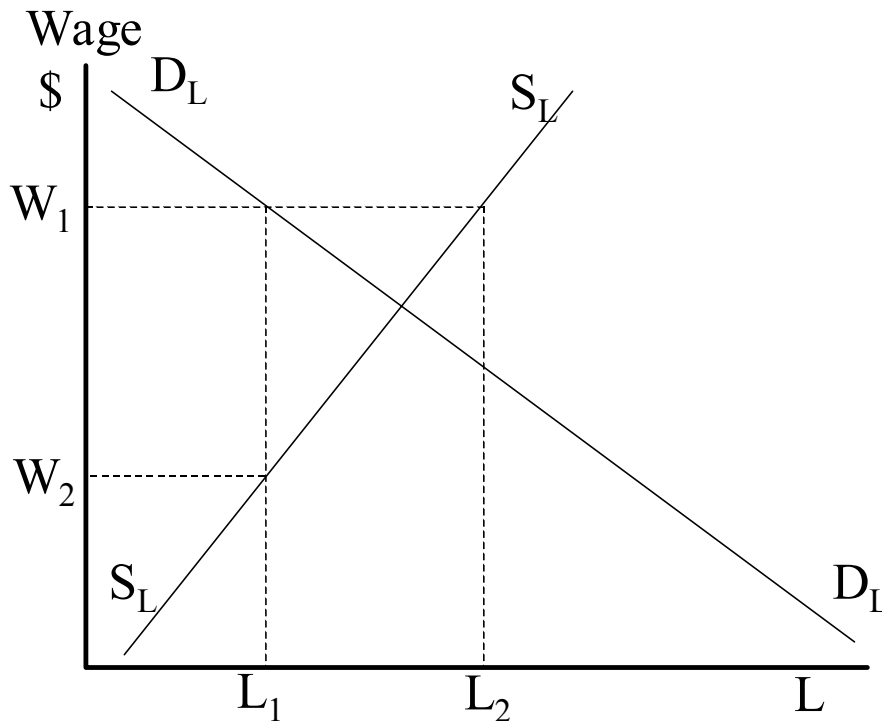
These are the external environmental costs -- net of mitigation measures -- due to port development, less the value of any environmental improvements. Potential port-related

the B-C test to pass this hurdle once market costs for resources were adjusted downward to reflect unemployment.

⁸Of course with prolonged unemployment, mobile (younger, healthier) workers will migrate to areas with better job prospects, by that reducing unemployment in the original area.

environmental costs and selected mitigation issues were described in some detail in Chapter IV. Again, the environmental effects of interest are incremental effects, i.e., the effects of the port over-and-above those that would occur without the port.

Figure V-2: Simplified Representation of RI Labor Market



Environmental externalities are presumed to be largely concentrated in and around the port area. As a result, environmental costs and benefits for the nation and the state will be very similar in most cases. Exceptions include costs due to delays at rail crossings from an increase in train traffic (an important and costly issue in the State of Washington, far from the ports of Tacoma and Seattle) and benefits if a port in one state reduces truck traffic on roads and highways in other states.

V. C. 4. Net Taxes and Fees

For a national assessment of benefits and costs, taxes and fees can be ignored as transfers—a reshuffling of financial costs among different groups.

From the perspective of state residents, a distinction must be made between fees and taxes levied on state residents and those collected from non-residents. Taxes and fees on residents are a transfer since the amount collected is essentially reshuffled among different individuals and groups within the state. Hence, taxes and fees normally can be ignored in assessing net benefits to an area.⁹ For this reason, in a benefit-cost analysis

⁹ An exception is when the marginal tax rate (or fee) is set so high that it modifies behavior, which can cause losses. For example, to the make the point, a hypothetical toll charge of \$200 per trip will drive a toll

for our illustrative case study, we would omit consideration of taxes collected on Rhode Island terminal workers, all of who are presumed to be from within the state.

However, a net gain is realized when a tax or fee is levied upon *outside parties*, to the extent that the amount collected exceeds the cost of services provided to them. This is because any net fiscal gain can be used to expand opportunities for residents to acquire valued goods and services without having to correspondingly reduce other outlays.

This issue can be important for a proposed port. A fee on all boxes moved, paid by a terminal operator in lieu of a leasing fee, potentially could be a very substantial sum, *if* moves through the port are high. To estimate the *net* gain, however, we must subtract the opportunity cost of the land used for the port, i.e., lease payments that would be received from the next-best use of the same land. Also, administrative and other costs related to collection of fees and servicing the port must be deducted from this gain. In the next section, we provide an illustrative example of the net gain from collection of a fee on container moves.

V. C. 5. Offsite Infrastructure Costs

Modern container ports require channels deep enough (at least 45 feet) to accommodate large vessels and also need convenient intermodal access for trucks and double-stacked trains to rail and highway routes that connect to hinterland markets. These are very costly investments. Additional maintenance costs that may be required due to wear and tear on roads also are an issue (e.g., Vitaliano and Hope, 1990). However, dredging of channels and construction of new or expanded offsite facilities, particularly roads, connectors, or overpasses involve public or collective goods--which can benefit all users, not just those associated with a container port.

Public investments in general, and public goods in particular, present several challenges for benefit-cost analysis and public policy. One is whether and to what extent an investment is an incremental cost of a container port or is something that would occur in any event. Another issue concerns the (optimal) scale of such investments, for example, the depth and width of channels and the width and quality of roads, interchanges, and connections. A third issue concerns how to assess the benefits of new facilities when they provide joint products—benefits to container port users and to the public at large. Clearly, several issues arise and need attention, but we did not address these issues in our Year One research.

V. D. ILLUSTRATIVE APPLICATION OF CONCEPTS TO CASE STUDY

To make the above discussion more concrete, some illustrative examples of selected benefits and costs are given next, using a port discussed for Quonset Point, Rhode Island, as an illustrative case study. We use only readily available data, and in some cases make strong assumptions in order to provide the illustrations. These examples will be refined

road or bridge use to zero, causing benefits for use of the facility to drop to zero since no one would use the road or bridge. Hence, an excessive tax or fee can affect benefits by influencing use.

and extended during later phases of our work. Hence, we made no attempt, in the first year of our research, to show a “bottom line” for the social benefits and costs of a hypothetical port development, and our illustrations are intended to show only how costs and benefits – including non-market costs and benefit -- can be quantified.

V. D. 1. Selected Financial Examples

V. D. 1. a. Savings in transportation costs.

According to a study by RK Johns and Associates (RKJA) (2000), the *delivered cost* of containers through a port at Quonset to many destinations in the northeast and Midwest would be as cheap or cheaper than moving containers through competing ports of New York/New Jersey (PNYNJ), Norfolk, Halifax, and Montreal (pp.3-3; 7-3). To the extent this is the case, users will realize a savings in transportation costs.

Concerning potential transportation savings to state residents, RKJA (2000) estimate that if all goes as projected, 26,599 containers with destinations in RI and Boston would move through Quonset in the first year (RKJA, p.7-6). The savings per move are unclear, and no doubt, differences would occur within the state depending upon location and access.

For this exercise, we explore the potential savings per move from using Quonset as follows. Many of the containers shipped to or from RI currently go through the PNYNJ, a distance of about 175 miles. With a new port, the average trucking distance to a destination in Rhode Island from Quonset would be, say, 40 miles. If the trucking cost is \$2 per mile, then the savings in trucking cost from using Quonset would be \$270 per box ($= (175-40) \times \2). However, RKJA also projects savings from lower terminal charges at a Quonset port versus PNYNJ. If Quonset charges \$200 per box, a figure mentioned in past studies, but PNYNJ charges \$300, there is a \$100 saving per box at the terminal. Hence, total savings could be as much as \$470 per move.

If half of the 26,599 containers estimated by RKJA for RI and nearby MA markets were to be shipped to or from Rhode Island businesses, the first year transportation cost savings to Rhode Island would be some \$6.2 million ($= (26,599 \times 470) / 2$). Future savings must be projected and discounted to arrive at the present value of transportation benefits to state residents.

We emphasize that this illustrative example assumes a successful port with reliable service, regularly and timely schedule calls by shipping lines, and fees that make it worthwhile for businesses to use the port. We defer a more complete assessment of this issue until a later phase of our work when details of a possible port become clearer and progress with application of the model in Chapter II might allow us to better estimate this potential gain.

For national benefits, perhaps more than 90 % of projected first-year moves may go to non-Rhode Island destinations, some as far away as the Midwest (RKJA, 2000). Hence, the largest transportation benefit apparently will accrue to non-state users. Note that if

competing ports, such as the PNYNJ responds to a new port at Quonset by reducing fees, then RI businesses still receive a transportation benefit which can be said to be due to having a port--but other financial payoffs from the port of course would suffer.¹⁰

V. D. 1. b. Gains to Workers.

According to the RKJA some 166 workers (include dock labor, indirect labor, and administrative staff) will be employed at the terminal when operations start, and this work force will grow to 593 after 20 years of operation. The workers cost per hour to the operator given in RKJA includes wages, benefits, and an overtime factor for terminal workers (RKJA, p.6-2). To arrive at the wage paid, we reduce this number by 25 % to eliminate fringe benefits, under the argument that fringe benefits are likely to be about the same as in alternative employment. Other labor and administrative staff are paid a salary, which we also reduce by 25% for the same reason. According to RKJA, 100 % of these workers will be state residents.

For purposes of estimating net gains to workers, we adjust wage payments as described in a preceding section of this Chapter. We use the average monthly unemployment rate for the period 1960 – 2000. Figure V.3 shows that unemployment in Rhode Island follows a bi-modal distribution, with frequent months of near full employment – full employment appears to be about 3 % -- but many months with considerable unemployment. The average monthly unemployment rate over the entire period was 6.8%. *We will assume in the calculations below that the unemployment rate is 6.8 % over the life of the project.*

We assume that the share of wages that represents a gain to workers increases linearly from 5% at full employment (3 %) to 31% at the highest level of unemployment included in our data, 9 %. Given this assumption, and the average assumed rate of unemployment of 6.8%, the implied adjustment factor we use to estimate the net gain to port-related workers is 21.3 %:

$$\begin{aligned}\text{Adjustment factor} &= (W_1 - W_2) / W_1 = .05 + 4.3 (\text{Unemployment Rate} - 0.03) \\ &= .05 + 4.3(0.068 - 0.03) = \mathbf{0.213}\end{aligned}$$

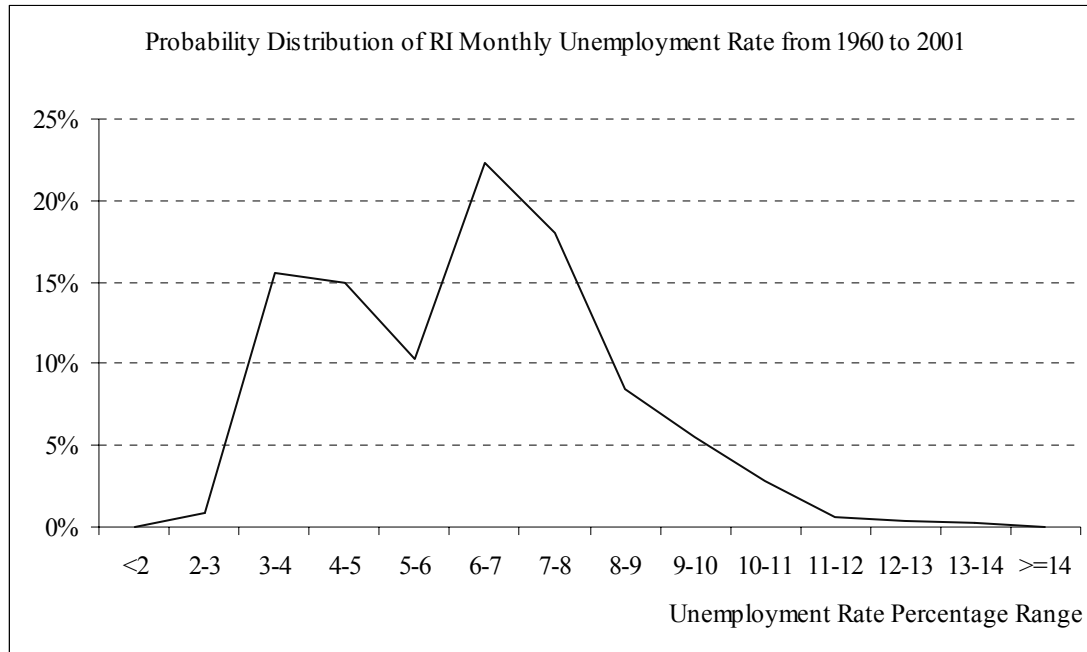
We note that port workers will tend to be younger, physically more fit, and have greater mobility as compared to the average worker in the state labor force. Hence, the opportunity cost of those hired is likely to be closer to the wage than the “average worker” and the corresponding adjustment to estimate gains to workers is likely is lower than 21.3%.

When we reduce market wage payments to reflect the value in alternative uses (opportunity cost) of the workers concerned, using the methodology and assumptions described above, the present value (@ 7%) of the gain to workers is \$70 million. This

¹⁰ Competitive responses by ports is extremely important in the container port business. The PNYNJ's plan to construct barge facilities and an inland port in New England are good examples of this competition (Moffat and Nichol, 2001).

gain is considerably less than total wages paid by the port (present value of \$333.3 million), but is by no means trivial.

We note that not all categories of direct workers mentioned in RKJA have been considered, nor have we included indirect workers calculated by RKJA. These other workers largely fall into the indirect and induced area, or represent *costs* of administering the port (e.g., government employees).



V. D. 1. c. Fees and taxes.

State residents will gain from collection of fees on container moves. This is because these fees primarily come at the expense of out-of-state users of the port (and according to RKJA) perhaps 90% of the containers will be shipped to markets outside of Rhode Island).

By one account, there could be a fee of \$75 per move, for 50,000 moves at the first year of operation up to 500,000 moves at the 10th year of operation, in lieu of annual lease payments (RKJA, 2000). The amount received in such fees can be a considerable, up to \$37.5 million annually after year 10. In a full analysis, the fees collected could be estimated for each year using our port model (Chapter III) and discounted to assess the present value of income from this source.

However, from the total fees collected we must subtract the lease payment the state would have receive from any *other* use of the land (i.e., the opportunity cost of the land). We use an estimate of annual rental fee of \$17,500 per acre per year as the opportunity

cost of port land at Quonset Point¹¹. Given the use of about 270 acres for a port, the annual opportunity cost of the land in terms of foregone lease payments in another activity is \$4.7 million.

Further, administration of terminals requires an organization – typically, a Port Authority -- with staff of professionals who oversee port operations, market the port, provide public relations, ensure compliance with environmental regulations, and carry out other activities. For example, RKJA (2000) project the need for 29 government employees at startup, growing to 137 at 20th year of operation.

Employment of government staff to administer and promote port functions involves a cost, not a benefit, since these workers will be drawn away from (i.e., come at the cost of) other valued activities, just like any other use of labor. Assuming an average wage and benefits of \$75,000 per year, the transactions cost for the port would be roughly \$2.17 million at startup and reach \$10.3 million at peak (in constant dollars). Other administrative costs are not considered here. Again, these costs would be discounted to arrive at a present value. This number would be subtracted from the port fees collected, as described in the above paragraphs.

In sum, peak annual fees collected on container throughput could be \$37.5 million. From this we subtract the foregone annual lease receipts from the port land in alternative uses of \$4.7 million, and peak administration (labor) costs, which are about \$10.3 million. Hence, the peak year fees, net of the costs considered here, is some \$18.8 million. These calculations put this potential benefit to state residents in some perspective but undoubtedly need considerable refinement beyond what was possible in our Year One report.

V. D. 2. Selected Environmental Examples

Here, we illustrate quantification of several types of potential environmental costs to the public due to port development. The examples used are costs from the perspective of both state residents and the nation.

V. D. 2. a. Marine Dredge Disposal.

In the Quonset Point case study, dredging of approach channels and of a turn around basin to 45 feet or more would be required to accommodate large container ships. Substantial volumes of materials (up to 10.4 million cubic yards) would be dredged and used either as fill for additional terminal space, for construction uses, or for beneficial uses; the balance (three million in 2 port alternative cases, nil in the other two) would be disposed of in marine waters, perhaps in Rhode Island Sound (RFJA, 2000, p.5-8).

Hence, under two port design options, some 3 million cubic yards of clean (i.e., non-contaminated) material dredged in the approach channel and turnaround basin would be

¹¹ Currently, (October 2001) port land at Quonset Point can be leased for \$15,000-\$20,000 acre/year, with the exact fee subject to negotiations (J. Riendo, RIEDC, pers. communication) but may be negotiable.

disposed of in marine waters (RKJA, p.5-8). Elsewhere, we (Grigalunas, Opaluch, and Luo, 2001). have estimated that the cost of disposal to fisheries of 5.1 million cubic yards of clean sediment at site 69b in RI Sound. The estimate included the short- and long-run effects and ecological (food web) effects on commercial and recreational fisheries and amounted to \$303,000 or \$0.06 per ton of clean sediment at this disposal site (Grigalunas, Opaluch, and Luo, 2001). (See Chapter IV for details.)

Assuming the same cost per ton is imposed by dredge material for the Quonset port as for the case reported in Grigalunas, Opaluch and Luo (2001), the approximately 3 million cubic yards disposed of at RI Sound site 69b would result in a present-valued cost of some \$178 thousand to fisheries, unless offset by mitigation actions.

V. D. 2. b. Loss of Bay Bottomland Due to Fill.

The four port designs given in RKJA involve filling from 28.8 to 114 acres of Narragansett Bay. Unless offset by mitigation elsewhere, this action would cause loss of the marine productivity of the filled lands in perpetuity. To provide some perspective on the cost of lost Bay bottom, we again draw upon the results from Grigalunas, Opaluch, and Luo (2001).

In their study, estimates were made of the cost to commercial and recreational fisheries of disposal of clean sediments at potential sites in Narragansett Bay and Rhode Island Sound (Grigalunas, Opaluch, Luo, 2001). These estimates ranged from \$329 (site 16) to \$3,660 (site 158) *per acre per year*. These are *overstated* cost estimates due to the conservative assumptions deliberately used for the study in question. These results imply a *permanent, per acre loss* of the bottom land ranging from \$4.7 thousand to \$52.3 thousand. If these values are representative of the productivity of the area of the Bay that would be filled, the implied lost value would be \$131 thousand to \$6 million for the 28.8 to 114 acres that could be filled, depending upon the option being considered. Of course, the biological productivity of the actual area to be filled may differ considerably from those given in Grigalunas, Opaluch and Luo (2001); field studies or available information would greatly refine the estimates given here.

V. D. 2. c. Loss of Wetlands

One option given in RKJA, Quonset II, would cause the loss of 9.8 acres of Fry's Cove (RKJA, p. 4-14). A recent estimate for the nearby Peconic estuary provides suggestive asset values for the public of \$54,000 per acre for wetlands (Opaluch, et al., 2000; Johnston, et al., 2001). This provides a suggestive loss on the order of \$530,000, unless mitigation is carried out to eliminate these potential losses.

V. D. 3. Other Examples

Potential environmental consequences of port development activity may affect the quality, and not necessarily the quantity, of resource services, such as loss of neighborhood

natural amenities. Examples of such potential impacts include the loss of open space and air and noise pollution.

Different methods are needed to address different economic values caused by external costs due to port development. Below we provide two examples of quantification of other potential costs of port development using the results of two recent studies with which one of the authors of this paper was involved.

One approach uses revealed preferences, an indirect approach in this case using a hedonic price function to assess the losses in environmental amenities as reflected in property values. The second example uses a stated preference approach, which estimate people's willingness to pay for preservation or restoration of natural resources, using the contingent choice method (see Chapter IV).

Both of the examples used are from an area near where a case study port (being considered for Quonset, Rhode Island) is being considered. Hence, the results may be suggestive of non-market values that might apply, with appropriate adjustments, to the port case study area.

V. D. 3. a. Amenity Effects on Neighboring Property Values

Unless avoided by design measures or by mitigation, port development may impose external costs on nearby residential communities from intense lighting and noise, or may cause more intensive or extensive development of lands in communities, by that causing a loss of local amenities, such as open space. Here we consider as an example the amenity value of open space to neighboring property owners.

Since there is no direct market for open space amenities as such, direct market evaluation for this quality change is not possible. However, amenity affects will be reflected in neighboring property values. Thus, observable property price changes can be used to infer the value of the environmental amenity (which is not directly observable) by the use of hedonic price function (e.g., Freeman, 1993), as we describe below.

Hedonic evaluation assumes the price of the property is a function of a set of attributes describing the property itself and environmental amenities, such as air quality, water quality, scenic views, acres of nearby open spaces, wetlands, etc. Data on actual property transactions can be used in a regression analysis where the observed market price of the property is viewed as a function of a set of site (e.g., lot size), neighborhood (e.g. distance to highway, schools), and environmental (e.g., proximity to open space) attributes. From this statistical relation (i.e., the hedonic price function) the marginal impact on property value of an environmental amenity (e.g., open space) can be estimated.

An example of the economic evaluation for the loss of open spaces is illustrated in a study by Johnston et al., (2001). This study used all (n=367) property transactions for 1996 for the Town of Southold on north fork of Peconic Estuary, NY, USA. Analysis of spatial aspects was facilitated using a Geographic Information System. Estimates of a

first-stage hedonic price function (using a transcendental function specification) found that property located adjacent to open space was worth 12.83 percent more, on average, than other homes, allowing for the influence of other factors affecting the value of the property (Johnston *et al*, 2001).

Using such a method, the loss of open space due to port development could be translated into a loss of amenity services to nearby property owners. For an assessment of the any economic cost due to port construction, a challenge would be to isolate development of open space due to the port over and above development of the space in the absence of a port.

The Hedonic method also is potentially very useful for examining the effect of noise or other externalities from port development when the effect can be observed through the property market. With such results, one could include the estimate of the associated external cost in an overall benefit-cost analysis of the proposed project, or the results could be used to compare the costs and benefits from noise suppression mitigation actions (e.g., use of sound-dampening fences, construction of berms, and equipment design) or with mitigation actions, such as purchase of open space elsewhere.

V. D. 3. b. Public Goods Effects of Natural Resource Amenities.

The hedonic price function outlined immediately above provides estimates the use value of the amenity change through its impacts on neighborhood (i.e., local) property values. However, the hedonic model does not include any “existence” value that the public at large might have for the target environmental resources. For example, the general public, beyond those residing in the immediate neighborhood, may also value area amenities, such as open space, wetlands, and farm lands, even if their properties are some distance away. Excluding this value, therefore, will underestimate the total value of losses due to reduction in broader area public good amenities.

Port-related development that causes a net loss of open space, wetlands, or other amenities could impose losses on the community at large, unless compensated for by mitigation. A recent study using a contingent choice framework (Mazzotta, Opaluch, and Grigalunas, 2001) examined this issue for the Peconic Estuary on Long island, in NY. The contingent choice survey asked respondents, in a carefully developed questionnaire, to choose between two programs, each which concerned preservation and restoration of specific resources, including open space and wetlands, for a specified cost per year for each household. “No action” also was an option.

The study found that residents and second homeowners (the area studied is a major summer vacation destination, with many summer homes) have a strong preference and willingness to pay for preservation and restoration of open space, wetlands, agricultural farms, eelgrass (a productive habitat for fish and shell fish) and other natural resources. Although the relative ranking of resources was more robust than the estimates of dollar values in this case, the suggestive results (from a nested logit model) show that the public had the highest marginal value for farmland (\$74,562/acre), followed by eelgrass

(\$69,962/acre), wetlands (\$56,669/acre), shell fishing areas (\$31,742/acre) and undeveloped land (\$14,024/acre).

Summing up these two examples, we should note that the first example given above uses the change of property value due to the loss of environmental amenities, and hence only reflects amenity losses to nearby property owners. In contrast, the second example provides estimates the broader value that the public at large has for preservation and restoration of area environmental resources. Therefore, the two examples present estimates of different values the public holds for the same environmental resources. Note also that there is a possibility of some double counting of losses, if the willingness to pay by individuals in the contingent choice study also includes the value they hold for neighboring amenities. In such a case, adding the estimate of nearby property value changes due to alteration of open space to the value estimated using contingent choice would count the neighborhood value twice. Thus, the two approaches might be viewed as establishing bounds for the amenity losses of a change in a resource with the lower bound given by the hedonic results and the upper bound by the contingent choice result.

V. E. Summary and Conclusions

Our use of social benefit-cost analysis as part of our framework has as its goal the assessment of the economic consequences of proposed container port development, including market and non-market effects. We defined the social benefits and costs of interest to be (1) national benefits and costs, due to our interest in national transportation policy, and (2) benefits and costs to current state residents, since container port policy is largely implemented at the state level, and it is current residents and public officials who debate, in various arenas, whether and under what conditions, ports are developed.

Concepts for considering the incremental benefits and costs of a new port were explained, and then selected, illustrative examples were used to make the discussion more concrete. A port being discussed for Quonset Point, Rhode Island was used as an illustrative case study using readily available (and admittedly, preliminary and imperfect) data and a series of judgments and assumptions.

As was illustrated, the benefits from transportation cost savings to the state from a successful port can be non-trivial. While the port itself is not labor intensive, the net gain to terminal workers (almost \$70 million in present value terms, in our example) is not inconsiderable. Similarly, potential fees, net of administrative labor costs also were non-trivial in our illustrative example. Of course, these results assume that the port is successful; and as we stressed in Chapter III, existing studies rely on strong, optimistic assumption (high start up volumes and growth, high efficiency, good intermodal connections, no labor problems, and limited retaliation by competing ports). In short, insufficient data exists at this point to reach a firm conclusion on the feasibility of a container port and our case study example is merely intended to illustrate use of our framework and the concepts and methodologies on which it is based.

At the same time, development can impose a variety of external environmental costs, unless avoided by design or through mitigation. Selected, illustrative examples were used to illustrate quantification of some environmental issues. The examples used included loss of bottom lands due to filling in of Bay waters, costs due to disposal of dredge material in marine waters, the value of lost wetlands, and loss of open space amenities. Mitigation or design measures may offset these external costs, but of course mitigation and redesign are not free. These costs also must be included but were not estimated in this Year One report.

We recognize that many other issues have not been addressed (see Chapter IV) in this report. As noted, our purpose was to present our “Comprehensive Framework”; implementation and refinement of elements of this framework are the subject of ongoing research.

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